Effects of Fire on Mexican Spotted Owls in Arizona and New Mexico

by Paul Beier

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Final Report

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ABSTRACT

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In 1993 the Mexican spotted owl (*Strix occidentalis lucida*) was listed as a threatened species by the US Fish and Wildlife Service, in part because of the rising potential threat to its habitat from catastrophic wildfires. Little research has been conducted to date examining the effects of fire on spotted owl presence and reproduction. In 1997 I surveyed 33 territories that had some level of fire in the previous 4 years, ranging from light controlled burns to near-total stand-replacing wildfire, and compared owl occupancy and reproduction in these burned territories to 31 unburned territories that had similar habitat and topography. The burned territories varied widely in terms of percent burned, severity of burn, cover type and topographic characteristics, so I also looked at trends of owl presence and reproduction in response to these variables. The presence of recent fire in a territory showed no evidence of affecting whether owls will be present or reproducing at that location (Sign test; $p = 0.115$). Discriminant function analysis and Multiple Response Permutation Procedures showed that the percentage of pine in a burned territory had the most influence on owl response, and that none of the fire severity variables had any significant and biologically interpretable influence on owl response. I attempted to find associations between fire severity and topographic/vegetative characteristics in spotted owl territories using Classification and Regression Trees (CART), but this analysis was severely limited by the lack of information on weather, climate and fuel moisture during the fire and results were inconclusive. Relatively light fires, including most prescribed fires, probably have no clear short-term positive or negative impact on Mexican spotted owl presence or reproduction, but they may indirectly benefit the owl by reducing the threat of potentially harmful wide-scale stand replacing fires.

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TABLE OF CONTENTS

LIST OF TABLES v

LIST OF FIGURES vi

INTRODUCTION 1

LITERATURE REVIEW 3
- **The Spotted Owl** 3
  - General Characteristics 3
  - Threatened Status 5
- **Fire and Forest Change** 6
  - Stand-maintenance vs. Stand-Replacement Fires 6
  - Changes in Forest Composition since Presettlement Conditions 8
  - Prescribed Fire, Prescribed Natural Fire and Wildfire 10
- **Effects of fire on owls** 12
  - Effects of Fire on Owl Prey 12
  - Forest Service Management Plans 17

METHODS 18
- **Study Area and Territory Selection** 18
  - Cores, PACs and CACs 18
  - Field Season 21
  - Calling Methods 21
  - Survey Locations 21
    - Fixed calling points 22
    - Calling routes 22
    - Leap-frog method 22
  - Record keeping 22
  - Owl Response Level 23
    - Absence 23
    - Single 24
    - Pair Occupancy 24
    - Reproduction 24
  - Complete Surveys 24
  - Paired Territories 24
- **Determining Fire Severity and Cover Type** 25
  - Slope 27
  - Aspect 27
  - Topographic Roughness 27
  - Research Question 1: Sign Test 29
  - Research Questions 2 and 3: MRPP and Discriminant Analysis 30
    - Three territory delineations 30
    - Significance Tests 31
    - MRPP 32
    - Bonferroni Correction 33
    - Spearman's Rho Correlations 34
    - Stepwise Discriminant Analysis 34

Discriminant Analysis Assumptions 35
Research Question 4: CART 37

RESULTS 40
Comparison of Burned and Unburned Territories 40
Influence of Fire Severity, Topographic and Habitat Variables on Owl Response ... 42
400-m CACs 42
OFS territories 47
1-km CACs 51
Influence of Slope, Aspect and Cover Type on Fire Severity 54

DISCUSSION 55
Comparison of Burned and Unburned Territories 55
Variables associated with Owl Response within the 33 burned territories 56
% Pine 56
% Unburned 57
% Stand Replacing Fire 57
Average Slope 58
Topographic Roughness 58
% East-Facing Slope 59
% Mixed Conifer 59
% North-Facing Slope 60
Variables associated with Severity of Burn within the 33 burned territories 60
Comparison of three territory delineations 61
Suggestions for Future Research 61
Length of time since the fire 62
Season of fire 62
Fire proximity to nesting and roosting stands 62
Repeated fires vs. Single events 62
Management Implications 63

LITERATURE CITED 64

APPENDIX A: Field Data Forms 74

APPENDIX B: Individual Territory Summaries and Maps 81

APPENDIX C: CART Analyses on Point Data 129

LIST OF TABLES

Table 1: Prey species or groups comprising ≥ 10% of Mexican spotted owl diet, in terms of either relative frequency or total biomass 14

Table 2: Variables measured or derived for each burned territory 28

Table 3: K-S Normality Tests of Fire Severity, Topographic and Habitat Variables in three territory boundary delineations 33

Table 4: K-S Normality Tests of Fire Severity, Topographic and Habitat Variables, in three territory boundary delineations, following Square-Root transformations in 3 variables 36

Table 5: *Box's M* tests of equal covariances of all predictor variables among the four levels of Owl Response 37

Table 7: Frequencies and significance level of sign test, measuring *Response Level of Unburned Territory - Response Level of Paired Burned Territory* 41

Table 8: MRPP Results for three territory boundary delineations 42

Table 9: Spearman's Rho Correlations - 400m CACs: 45

Table 10: Steps in stepwise discriminant analysis classification model development for 400-m CACs, OFS territories and 1-km CACs 46

Table 11: Classification Function Coefficients for 400-m CACs 46

Table 12: 400-m CACs - Cross Validations and Predictive Accuracy of Discriminant Analysis Model 46

Table 13: Spearman's Rho Correlations - OFS territories 50

Table 14: Classification Function Coefficients for OFS territories 51

Table 15: OFS territories - Cross Validations and Predictive Accuracy of Discriminant Analysis Model 51

Table 16: Spearman's Rho Correlations - 1-km CACs 53

Table 17: Classification Function Coefficients for 1-km CACs 54

Table 18: 1-km CACs - Cross Validations and Predictive Accuracy of Discriminant Analysis Model 54

Table 19: Typical prediction criteria developed by CART illustrating inconsistency in classification 55

LIST OF FIGURES

Figure 1: Distribution of Surveyed Mexican Spotted Owl Territories 20

Figure 2: Hochderffer Territory on the Coconino National Forest, showing initial grid sampling pattern and resulting *Fire Severity* and *Cover Type* maps 26

Figure 3: Example of a CART Classification Tree 38

Figure 4: Distribution of three predictor variables in 400-m CACs 43

Figure 5: Boxplots of *% East-Facing Slope* in 400-m CACs 46

Figure 6: Boxplots of *% North Aspect, % Stand-Replacing Fire, % Pine* and *% Mixed Conifer* predictor variables in OFS territories 48

Figure 7: Boxplots of *Average Slope* and *Topographic Roughness Index* predictor variables in OFS territories 49

Figure 8: Boxplots of *% Unburned, % Pine* and *% Mixed Conifer* predictor variables in 1-km CACs 52

INTRODUCTION

The fire ecology of forests in the Southwest has changed drastically in the last century due to such management practices as fire suppression, timber harvesting and grazing (Fulé et al. 1997; USDA Forest Service Southwestern Region 1995; Kolb et al. 1994; Sackett et al. 1994; National Commission on Wildfire Disasters 1994; Covington and Moore 1994a, 1994b; Covington et al. 1994; Moody et al. 1992; Harrington and Sackett 1990; Wright 1990; Arno and Brown 1989). These management practices have altered the natural conditions of the forests by producing more litter and combustible debris on the ground as well as a denser understory of shrubs and small trees. This combination of factors has created a highly combustible forest and increased the potential for more and larger fires, which could drastically alter and possibly destroy wildlife habitats.

The Mexican spotted owl, *Strix occidentalis lucida*, is one animal that could be dramatically affected by fire. This owl was listed as a threatened species by the U.S. Fish and Wildlife Service in 1993, based on historical and ongoing habitat alteration due to timber management practices and the threat of additional habitat loss from catastrophic wildfire (USDI Fish and Wildlife Service 1995). There is some concern among land managers that large-scale stand-replacing fires occurring throughout the owls' range could damage owl habitat. However, small-scale stand-maintaining fires may actually benefit the owl by creating habitat features such as canopy gaps, snags, and logs, and may also improve small mammal habitat which in turn would enhance prey populations. Small-scale fires might also benefit the owl by reducing the risk of large-scale fires (USDI Fish and Wildlife Service 1995).

In this study I examine the impacts of fire on Mexican spotted owls in Arizona and New Mexico by comparing the presence and reproductive success of owls on territories that have recently been burned by forest fire, with the presence and reproductive success of owls in similar, but unburned, territories. I then examine physical characteristics within the burned

territories, such as severity and extent of burn, topographic characteristics of the territory and dominant forest cover type of the territory to look for correlations with owl occupancy and reproductive success.

This research effort can be broken down into 4 subquestions:

1. QUESTION: Does the presence of fire within a territory influence owl territory occupancy and reproductive success?
   a) OBJECTIVE: Compare occupancy and reproductive rates between burned and unburned territories.
2. QUESTION: Does the severity and extent of fire within a burned territory influence spotted owl occupancy and reproduction?
   a) OBJECTIVES:
      (1) Describe fire in terms of severity and percent of territory burned.
      (2) Relate owl occupancy and reproduction to levels of fire severity.
3. QUESTION: Do topographic characteristics or dominant cover type of a burned territory influence spotted owl occupancy and reproduction?
   a) OBJECTIVE: For each burned territory, describe the average slope, % aspect in four directions (north, east, south and west), and dominant vegetative type, and relate owl occupancy and reproduction to these characteristics.
4. QUESTION: Do the topographic characteristics or the dominant vegetative cover type influence the pattern of burn within spotted owl territories?
   a) OBJECTIVE: Look for patterns of interaction between these topographic and vegetative characteristics and the severity of burn within the territory.

LITERATURE REVIEW

The Spotted Owl

General Characteristics: The Mexican spotted owl is a resident raptor species found throughout the mountains and canyons of Arizona, New Mexico, southern Colorado and Utah, and northern and central Mexico. Most of these birds reside in a band of mixed-coniferous and ponderosa pine/Gambel oak (*Pinus ponderosa/Quercus gambelii*) forest stretching southeast from the southern portion of the Kaibab National Forest in northcentral Arizona down to the Gila National Forest in southwestern New Mexico. There are also substantial subpopulations located in the Sky Island mountain ranges in southern Arizona and in the Sacramento Mountains in southern New Mexico (Ward et al. 1995)

Adult Mexican spotted owls likely have a relatively high survival rate, with the probability of an adult surviving from one year to the next estimated at around 0.8 - 0.9 (White et al. 1995). Juveniles, on the other hand, have a much lower survival rate, ranging from 0.06 - 0.29 (Ganey et al. 1998; Willey 1998; White et al. 1995). There is a great deal of spatial and temporal variation in reproductive output, but one estimate places the general reproductive rate at 1.001 fledglings per pair (White et al. 1995). As is typical for *K*-selected species (Ricklefs 1990) the owl is long-lived with low reproductive output and generally maintains population densities near carrying capacity. The high survival rate of *K*-selected species enables them to maintain stable populations over time despite variable recruitment rates (White et al. 1995). The high survival rate of adult Mexican spotted owls may also help them to withstand fluctuations in habitat quality, such as might be expected from periodic fire within their territories.

Mexican spotted owls typically nest and roost in structurally-complex, diverse forests with a variety of age- and/or size-classes, a component of large trees, often with many snags and down logs and relatively high basal areas and canopy closures (Ganey et al. 1999; Ganey and

Dick 1995). These conditions are typical of old-growth type forests that have generally had minimal human-caused disturbance (Helms 1998). Ganey and Balda (1994), in a study of radio-tagged owls in northern Arizona, found that they did not forage randomly among available habitat types. Rather they tended to be found more often than expected (assuming random habitat selection) in unlogged forests and less often in managed forests, and they were rarely found in non-forested areas.

Mexican spotted owls generally nest in trees, although in the northern part of their range (southern Utah and Colorado) they often nest in caves or cliff ledges in canyons, and seem to prefer shady habitat with steep cliffs and rocky terrain (Willey 1998; Rinkevich et al. 1995). Vegetative components of their habitat vary spatially, with owls in the northern part of their range typically residing in forests dominated by mixed-coniferous species such as Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*) and ponderosa pine in conjunction with broadleafed species such as Gambel oak, maples (*Acer* spp.), boxelder (*Acer negundo*) and New Mexican locust (*Robinia neomexicana*) (Rinkevich et al. 1995; Ganey et al. 1992). In the southern part of their range (southern Arizona and Mexico), these owls typically occur in Madrean pine/oak forests dominated by Chihuahua pine (*Pinus leiophylla* var. *chihuahuana*), Apache pine (*Pinus engelmannii*) and southwestern white pine (*Pinus flexilis* var. *reflexa*) in conjunction with evergreen oaks, Douglas-fir, ponderosa pine and Arizona cypress (*Cupressus arizonica*) (Rinkevich et al. 1995; Ganey et al. 1992; Kroel and Zwank 1991). A few individuals have been observed to migrate downslope in the winter to Pinyon/Juniper (*Pinus edulis*/*Juniperus* spp.) dominated habitats (Ganey et al. 1992).

Within the United States portion of their range, Mexican spotted owl nest and roost sites have primarily been found in mixed conifer stands, occasionally in pine/oak stands and very rarely in pine, evergreen oak, pinyon/juniper, riparian or other stands. Ganey and Dick (1995),

reviewing Mexican spotted owl inventory data gathered between 1990 and 1993 from various parts of the owls' range, found that 69% - 100% of nest sites were located in mixed conifer stands, 0% - 28% were in pine/oak stands and 0% - 2% were in pine stands. Roost sites were similarly distributed, with 49% - 99% in mixed conifer, 0% - 36% in pine/oak and 0% - 2% in pine.

Spotted owls are primarily nocturnal predators. Diurnal observations of Mexican spotted owls in Utah revealed that the owls spent 90% of the observation time roosting quietly (Willey 1998). Although spotted owls primarily hunt at night, they will opportunistically take prey who wander near their roost in the daytime. Nesting owls are significantly more likely to take prey in the daytime than non-nesting owls (Sovern et al. 1994).

They cannot hunt efficiently while flying (Carey et al. 1992), so they generally use a "sit-and-wait" hunting strategy in which they wait for prey animals to come near their location. Structurally complex forests with high vertical diversity are well-suited for this type of hunting strategy because they provide perches from ground level to the upper canopy (Carey et al. 1992).

Threatened Status: Both the Mexican and the northern spotted owl (*S. o. caurina*) have been listed as threatened by the US Fish and Wildlife Service, in part due to the historical and ongoing alteration of their habitat from timber harvesting (Block 1994; USDI Fish and Wildlife Service 1995). Restriction of timber harvesting and the ensuing economic, social and political impacts have prompted a great deal of research on this species. Following the listing of the Mexican spotted owl on April 15, 1993, the USDI Fish and Wildlife Service appointed a recovery team and gave them the task of compiling the current knowledge on the owl and developing a plan to recover the owl. This recovery plan was released in 1995 (USDI Fish and Wildlife Service 1995).

Although we may know more about the ecology and status of the spotted owl than we do about any other threatened or endangered species (Gutierrez 1994), much of the research has

focused on the northern spotted owl. Comparatively little research has been conducted on the Mexican spotted owl, particularly in regard to this bird's response to fire (Howe et al. 1992). Habitat use, habitat distribution, and threats differ between the northern and the Mexican subspecies (USDI Fish and Wildlife Service 1995). Based on genetic analysis, Barrowclough and Gutierrez (1990) even suggested that the Mexican spotted owl may be a separate species from the northern and California spotted owls (*S. o. occidentalis*), pointing out that there has been no gene flow between them for at least 7,000 years.

Fire and Forest Change

Stand-maintenance vs. Stand-Replacement Fires: Fires vary in their intensity, duration and size, based on fuel availability, vegetative conditions, topography, climate, temperature, weather conditions and attempts to suppress the fire (Wenger 1984). Given these factors, fire effects on ecosystems can be viewed over a continuum, ranging from small-scale low-intensity fires such as a single lightning-struck snag, to large-scale high-intensity fires such as those that burned a third of Yellowstone National Park in 1988.

Fire effects are often categorized according to the impacts the fire has on the ecosystem. In the interests of drawing practical conclusions from my research, I will follow the fire regime delineation described by Wenger (1984) in which fires are separated into either *stand-replacement* fires or *stand-maintenance* fires. Stand-replacement fires, often referred to as "catastrophic" fires, are characterized by moderate- to high-intensity fire activity that kills practically all vegetation within the fire boundary. The dead vegetative material left after the fire often creates an additional fuel hazard, leading to increased fire danger in the future. Stand-maintenance fires include low- to moderate-intensity fire activity which generally burns low to the ground and mainly affects grasses, shrubs, forbs and small trees. This type of fire typically burns off accumulated vegetative debris on the ground without killing larger trees, and

thus reduces the danger of future fires without causing major impacts on the current vegetative composition of the area (Wenger 1984).

I have further subdivided *stand-maintaining* fires into two categories. *Canopy-level* fire is that which burns into the canopy of some trees but does not cause complete mortality of all the trees in the area. *Surface-level* fire is that which burns only along the ground and never reaches the tree canopy.

DeBano et al. (1998) and Pyne et al. (1996) differentiate between the term *Surface fire*, meaning fire that only burns the litter, debris and small plants on the surface of the soil, and *Ground fire*, meaning fire that actually burns down into the organic material in the upper soil layer. This is a valid distinction to make because the effect on soil, microorganisms and root systems can be radically different between these two types of ground-level fire. Depending upon the depth, density, inorganic content and moisture content of the duff layer, this covering of decomposing plant material can either insulate the mineral soil from the heat of the fire or it can combust in a smoldering reaction that can potentially do great damage to the living material in the soil.

Agee (1993), DeBano et al. (1998) and Pyne et al. (1996) discuss at length the phenomena of vegetative mortality resulting from exposure to heat, each pointing out that exposure to temperatures above 60° C (140° F) is generally lethal to the plant. Smoldering duff does not produce flames so it does not reach the intense heat of actively flaming vegetative material, but it continues to smolder, and generate heat, for far longer than flaming fires burn. If flaming debris ignites the duff and environmental conditions are such that the smoldering reaction can sustain itself, smoldering duff can raise the temperature of the underlying mineral soil to 300° C (570° F) for several hours at a time, reaching temperatures as high as 600° (1100° F) and producing lethal temperatures down as far as 9-16 cm in dry soil and 40-50 cm in

moist soil (DeBano et al. 1998; Pyne et al. 1996). This type of ground fire can cause a great deal of mortality in the soil, including tree mortality when the roots are killed or the tree is girdled at ground level.

Both *Ground* and *Surface* fire appear to be stand-maintaining in the mixed conifer or ponderosa pine-dominated forests used by Mexican spotted owls. Grier (1989) found a general decrease in biomass production as a result of prescribed fire in a ponderosa pine forest in northern Washington, and Swezy and Agee (1991) found individual ponderosa pine mortality caused by fine-root mortality in shallow soils and crown scorch in Oregon, but this mortality was restricted to seedlings, immature trees and weakened senescent groups and actually served to maintain a vigorous overall stand structure. Kalabokidis and Wakimoto (1992), in a Montana study of prescribed fire in ponderosa pine and Douglas-fir forests, found no significant differences in duff depth between burned and unburned sites and little mortality in larger trees following prescribed fires. Ryan and Frandsen (1991) conducted experimental burns on the duff layers surrounding 19 large ponderosa pine trees in Montana and found lethal heating in 45% of cambium samples tested and the subsequent death of 4 of the 19 trees.

In essence, it appears that whether a fire burns into the soil or not does not generally cause differences in stand structure on a scale large enough to make a significant difference in spotted owl presence or reproduction. These studies, plus the fact that I visited some burned territories 3 years after the fire when I could not readily distinguish whether a ground-level fire was a *ground* or *surface* fire, led me to consider all ground-level fires as *surface* fires for the purposes of this study.

<u>Changes in Forest Composition since Presettlement Conditions</u>: Forests have changed drastically over the last 120 years due to management practices such as timber harvesting, grazing and fire suppression (Fulé et al. 1997; USDA Forest Service Southwestern Region 1995;

Kolb et al. 1994; Sackett et al. 1994; National Commission on Wildfire Disasters 1994; Covington and Moore 1994b, 1994b; Moody et al. 1992; Harrington and Sackett 1990; Wright 1990; Arno and Brown 1989). This idea is not new. Aldo Leopold, writing in 1924, described the encroachment of Pinyon and Juniper species into grasslands in the Tonto National Forest and the widespread buildup of brush species (oaks, manzanita [*Arctostaphylos uva-ursi*], mountain mahogany [*Cercocarpus* spp.] and ceanothus [*Ceanothus* spp.]) throughout many forests in Arizona, attributing both phenomena to fire suppression and grazing in the 40 years since settlement.

Estimates of presettlement fire frequency in southwestern forests vary somewhat, with the pinyon-juniper type burning approximately every 10-30 years (Wright 1990; Leopold 1924) the ponderosa pine type around every 1.8-12 years (Fulé et al. 1997; Covington and Moore 1994b; Swetnam 1990; Wright 1990; Dieterich 1980a, 1980b; Weaver 1951), and the mixed conifer type around every 5-22 years (Wright 1990; Ahlstrand 1980). Fires that burn at these frequencies (at around 2-25 yr. intervals) tend to be stand-maintenance fires rather than stand-replacement fires (Wenger 1984), and thus their main impact on the forest is to burn the ground-level fuel (woody debris, grasses, forbs, shrubs and small trees) while harming few of the larger trees.

Since fire suppression, cattle grazing and timber harvest began in the Southwest late in the 19th century, southwestern ponderosa pine forests have shown an increase in stand density, higher fuel loads, greater canopy closure, increased vertical fuel continuity, decreased vegetative decomposition rates and decreased fire frequency, all of which increase the potential severity and destructiveness of fires (Zwolinski 1990; Covington and Moore 1994a, 1994b). Crown fires, for example, are now common occurrences, and yet they were once almost unknown in the

Southwestern ponderosa pine forest type (Covington and Moore 1994b).

Ironically, historic fire suppression has probably had the greatest impact on current fire danger. When fires began to be actively suppressed, ground-level fuel began to accumulate. The dry southwestern climate aided this fuel buildup by inhibiting decomposition (National Commission on Wildfire Disasters 1994), and thus fuel loads have been growing faster than they can decay. The small trees that would normally have been killed in their first few years have instead grown into densely-packed stands of saplings and pole-sized trees (Covington and Moore 1994b; Covington et al. 1994), creating fuel ladders that carry the fire to the crowns of the larger trees.

Heavy grazing throughout the century has also contributed to the problem by reducing the grass and forb layer that would normally carry ground fire (National Commission on Wildfire Disasters 1994; Wright 1990). Elimination of the grass and forb layer also promotes the establishment and growth of tree seedlings by removing potential competition, eventually leading to the development of the dense sapling and pole-sized stands (Sackett et al. 1994).

<u>Prescribed Fire, Prescribed Natural Fire and Wildfire</u>: The origin of the fire may also play a role in how that fire affects the forest. Due to the previously described management activities over the past 120 years, wildfires tend to be far more intense and destructive than they were under presettlement conditions. However, wildfires often have the advantage of occurring during the natural fire season (primarily during the monsoon season between July and September [Fulé et al. 1997; Sackett et al. 1994] and to a lesser extent in late spring between late April and June [Fulé et al. 1997]), and thus burn plants at a time of year in which the plants have likely evolved mechanisms to cope with fire-induced damage. This advantage is, unfortunately, offset by the current unnaturally high fuel loads.

Prescribed burns, on the other hand, are typically conducted under wet or cool conditions

when there is little chance that the fire will turn into a large-scale stand-replacing fire. These conditions usually enable the land managers to control the fire and to accomplish specific management goals, and thus prescribed fire has become a very powerful and useful tool. Wildlife managers have found prescribed fire useful for creating diversity in habitat structure by breaking up homogeneous cover types (Severson and Rinne 1990).

The drawback to most prescribed fires, however, is that they rarely occur during the natural fire season. The natural fire season is typically a time at which the forest is in a highly combustible state and forest managers are often reluctant to start fires in areas with both extremely heavy fuel loads and highly combustible conditions. To reduce the threat of losing control of the fire, managers will often conduct prescribed burns under cooler, wetter conditions which generally occur outside of the natural fire season. For example, Harrington and Sackett (1990) recommend that prescribed burns in areas that have not been subjected to fire in decades should be conducted in the fall or early spring when temperatures and humidities are moderate. However, this off-season burning can have significant impacts on vegetative structure and species composition. Zwolinski (1990) points out that the season in which the fire occurs is an important factor in plant survival and reproduction, and Harrington and Sackett (1990) discuss seasonal variation in tree susceptibility to fire. DeBano et al. (1998) describe how moist soils conduct heat better than dry soils, and in cases of long-smoldering duff fires can carry lethal temperatures as deep as 50 cm below the surface. Lethal temperatures in dry soils rarely penetrate deeper than 16 cm (DeBano et al. 1998).

A recent development in fire management is the concept of the "prescribed natural fire." This refers to prescribing a fire for a certain area and waiting for a fire to start and burn there naturally. The area is typically prepared beforehand by prescribed fire or mechanical thinning in order to reduce the chance of catastrophic wildfire, and the prescribed natural fire then has the

advantage of burning during the natural fire season while accomplishing specific management goals (W. Block, pers. comm. March 15, 1996).

Effects of fire on owls

Few researchers have measured the effects of fire or fire suppression on any aspect of Mexican spotted owls. Some have speculated that spotted owls were not even present in many of their current areas prior to European settlement, and that the owls only moved in after forest management practices altered the landscape (National Commission on Wildfire Disasters 1994). Mexican spotted owls in the Gila National Forest have been observed to return to their territories after prescribed natural fires, provided that the stand structure remained intact (USDA Forest Service Southwestern Region 1995). Some California spotted owls apparently disappeared for several years following a highly destructive fire in 1977 (Elliott 1985). Gaines et al. (1997) describe some impacts of 1994 wildfires on 6 northern spotted owl activity centers in eastern Washington, noting a decrease in the number of reproductive pairs on these sites (although not much below the numbers in previous low years) and an increase in the number of unoccupied sites the year after the fires. Two pairs of radio-tagged northern spotted owls in south-central Washington stayed near their territories after wildfire but shifted their primary activity to lightly burned or unburned areas (Bevis and other 1997). One female owl in this study was found dead in an emaciated condition 2.5 months after the fire, leading to speculation that the fire may have damaged her prey base. Her mate disappeared over the winter and two new owls occupied the territory in 1995.

<u>Effects of Fire on Owl Prey</u>: Fire could affect Mexican spotted owls indirectly through their prey base. Spotted owls may select habitats partially based on prey availability (Ward and Block 1995; Verner et al. 1992), so fire-caused changes in prey populations could potentially alter the quality of the habitat.

The Mexican spotted owl recovery team reviewed a data set of 11,164 prey items

collected from 18 geographic areas within the owls' range (Ward and Block 1995). Ward and Block found that owl diet varied across the owls' range, and owl reproductive success was not influenced by the presence or abundance of any particular prey species. They hypothesized that owl reproductive success was, therefore, influenced primarily by the total prey biomass consumed rather than the presence or abundance of any particular species. However, unpublished information suggests that the reproductive success of spotted owls in the Sacramento Mountains of southern New Mexico was positively correlated with the abundance of deer mice (*Peromyscus maniculatus*) (Ward et al. [unpublished], cited in Ward and Block 1995).

Ward and Block found eight prey groups that comprise significant portions of the Mexican spotted owl diet (Table 1). Peromyscid mice, woodrats, microtine voles and birds each represented $\geq$ 10% of both the relative frequency and the total biomass of the owls' diet in at least one of the geographic recovery units delineated by the Mexican spotted owl recovery team. Bats and arthropods were taken in high numbers, but they have little mass and, therefore, did not represent $\geq$ 10% of the total biomass. Rabbits and pocket gophers, on the other hand, were taken relatively rarely, but they are larger animals and represented a relatively large proportion of total prey biomass.

The effects of fire on small mammals are varied. Some researchers (Buech et al 1977; Kirkland et al 1996) found general declines in overall rodent populations in some habitat types following a fire. Schwilk and Keeley (1998) found no difference in general rodent populations in burned and unburned chaparral and coastal sage sites. McGee (1982) found that the total number of mammals in a burned sagebrush site was similar to that in an unburned site, but that the species composition had shifted toward a higher percentage of deer mice.

Martell (1984) found significantly higher number of small mammals in a burned black spruce and mixedwoods forest type in the three years after a severe fire. Wirtz (1982) found that

the total biomass of all rodents on burned chaparral plots was low for the first year following a fire, but then increased rapidly from 15-30 months post-fire and by 34 months was higher than the maximum rodent biomass on the unburned plots.

Table 1: Prey species or groups comprising ≥ 10% of Mexican spotted owl diet, in terms of either relative frequency or total biomass (Adapted from data in Ward and Block [1995])

Prey Species or Group	≥ 10% of relative frequency of prey items[a]	≥ 10% of total diet biomass[a]
Peromyscid Mice		
Deer mouse (*Peromyscus maniculatus*)	X	X
Brush mouse (*Peromyscus boylii*)	X	X
Woodrats		
Mexican woodrat (*Neotoma mexicana*)	X	X
Bushy-tailed woodrat (*Neotoma cinerea*)	X	X
Desert woodrat (*Neotoma lepida*)	X	X
White-throated woodrat (*Neotoma albigula*)	X	X
Voles		
Mexican vole (*Microtus mexicanus*)	X	X
Mountain vole (*Microtus montanus*)	X	X
Meadow vole (*Microtus pennsylvanicus*)	X	X
Long-tailed vole (*Microtus longicaudus*)	X	X
Birds	X	X
Bats	X	
Pocket Gophers		X
Rabbits		X
Arthropods	X	

[a] Data reflect those prey species that comprise ≥ 10% of the Mexican spotted owls' diet in at least one out of seven geographic subdivisions of the owls' range.

Fire effects on small mammal abundance appear short-lived. The total abundance of rodents returned to pre-fire levels within 8 months in lightly burned oak woodland (Kirkland et al. 1996) and within 4-6 years after a severe fire in chaparral (Wirtz et al. 1988).

Peromyscus: Deer mice (*Peromyscus maniculatus*) were markedly more abundant in burned areas, compared to pre-fire conditions or unburned control areas (Martell 1984; Buech et al. 1977; Campbell et al. 1977; Fala 1975; Krefting and Ahlgren 1974; Beck and Vogl 1972).

Tevis (1956) found the combined numbers of two *Peromyscus* species (including *P. maniculatus*) increased to twice their pre-fire numbers within 2½ weeks following a hot slash fire in California. Wirtz et al. (1988), comparing medium and severe burns, found that areas that burned the hottest had the highest numbers of deer mice. Similarly, brush mice (*Peromyscus boylii*) increased their numbers by 6× in a medium intensity burn and by 14× in a high intensity burn two years after a fire (Wirtz et al 1988).

These high numbers of deer mice following fire have been attributed to the increase in seed-producing annuals appearing soon after a fire (Schwilk and Keeley 1998; Ahlgren 1966; Cook 1959) or to the removal of litter (Kaufman et al. 1988) and vertical vegetative structure (Clark and Kaufman 1990) by the fire. Deer mice numbers tend be highest within the first year or two following the fire, and numbers decrease thereafter (Kaufman et al. 1988; Krefting and Ahlgren 1974).

Woodrats: Few studies have directly addressed the effects of fire on woodrats. Schwilk and Keeley (1998), six months after a large fire in California chaparral and coastal sage, found desert woodrats (*Neotoma lepida*) in all 6 burned sites. Abundance of desert woodrats increased with distance from the edge of the burn (deeper into the burned area) in chaparral vegetation, but decreased with distance from the edge of the burn in coastal sage vegetation.

Voles: Two studies described some effects of fire on one of the microtine vole species eaten by Mexican spotted owls. Fala (1975) found that meadow vole (*Microtus pennsylvanicus*) numbers declined immediately after a fire, but within 1.5 years had risen to be equivalent to meadow vole numbers in unburned control areas. Geluso (1986) found that meadow voles avoided fire in a very hot prairie fire, finding refuges in burrows or on top of pocket gopher (*Geomys bursarius*) mounds.

Birds: Wirtz (1982) found that bird species diversity and abundance was enhanced

slightly after fire, possibly due to an increase in food resource diversity. Bock and Bock (1983) found 7 bird species more abundant in burned territories than in unburned controls, two of which (American robin [*Turdus migratorius*] and western tanager [*Piranga ludoviciana*]) have been identified in spotted owl pellets (Ward and Block 1995). Diversity and abundance returned to pre-fire levels within 4 years in chaparral (Wirtz 1982) and within 2 years in Ponderosa pine (Bock and Bock 1983).

Bats and Pocket Gophers: I was unable to find any studies that addressed the effects of fire on either bat or pocket gopher abundances.

Rabbits: Lochmiller et al. (1991), in a study of cottontail rabbits (*Sylvilagus floridanus*) in Oklahoma, found some evidence suggesting that prescribed fire had a positive impact on cottontail densities.

Arthropods: Ahlgren (1966) found large numbers of centipedes, caterpillars and beetles on burned areas. I was unable to find any studies that compared arthropod abundances between burned and unburned sites.

In summary, some Mexican spotted owl prey species show a decline or mixed response following fire, but many species, especially deer mice, increase in abundance following fire. Early successional specialists (such as the deer mouse) and species that require open habitats with well-developed herbaceous understories (such as pocket gophers or microtine voles) benefit from intense stand-replacing fires, while species that require dense canopies decline (Ward and Block 1995). Seed-eating species would find a sudden increase in their food supply when annual grasses come in.

Mexican spotted owls appear to be influenced more by the total prey biomass available than by the abundance of any particular species, with the possible exception of a potential positive association with deer mouse abundance in one geographic area. Total prey biomass

following fire appears to increase in some areas and decrease in others, while deer mouse abundance appears to universally increase. In general, it appears that fire will be more likely to improve the owls' prey base than to hurt it. The reduction in ground cover would also leave the prey more exposed and thus increase prey availability to the owl.

Forest Service Management Plans: The US Forest Service is currently in the process of amending forest plans to incorporate management direction for Mexican spotted owls. In the Final Environmental Impact Statement for this amendment, the Forest Service has expressed its desire to manage fuel loads in and around spotted owl territories with an aggressive combination of mechanical thinning and prescribed burning (USDA Forest Service Southwestern Region 1995). Sheppard and Farnsworth (1997) describe a prescribed burn project currently under way intended to reduce the threat of catastrophic wildfires within management territories. This project, begun in 1989, has used prescribed fire in and around nesting and roosting habitats in the Red Hill (Appendix B, p. 112) and Upper West Fork (Appendix B, p. 116) territories on the Coconino National Forest near Flagstaff, AZ. Both of these territories were included in this thesis study. Within the Forest Service-delineated spotted owl Protected Activity Center (PAC), the Forest Service intends to restrict fuel management activities to prescribed burning outside of the breeding season (USDA Forest Service Southwestern Region 1995). Given this expressed intention of the Forest Service, it will be valuable to know what effect different levels of fire have on occupancy and reproductive behavior of spotted owls within their territories.

The Mexican spotted owl recovery team (USDI Fish and Wildlife Service 1995), based on a general knowledge of the habitat requirements of the owl, stated that small-scale fires would be beneficial to the owl by creating canopy gaps, reducing fuel loads, thinning dense stands and generally reducing the chance of catastrophic fire. Small fires would also benefit both the owl and its prey base by creating snags and logs and perpetuating understory shrubs, grasses and

forbs. Large crown fires would be detrimental to the owl by reducing or eliminating nesting, roosting and foraging habitat (USDI Fish and Wildlife Service 1995). The Forest Service, in their Final Environmental Impact Statement, estimates that it could take 200 years to re-establish ideal conditions for the owl following a large-scale catastrophic fire (USDA Forest Service Southwestern Region 1995).

METHODS

Study Area and Territory Selection

Since the late 1980's, Forest Service biologists and technicians have conducted spotted owl inventories throughout many parts of the national forests in the Southwestern Region (Arizona and New Mexico), concentrating mainly on proposed timber sale areas and areas with suspected high-quality spotted owl habitat. This effort has documented many spotted owl territories in Arizona and New Mexico, with several consecutive years of data regarding owl presence and reproduction for many territories. The Forest Service also maintains an excellent record of fires occurring on national forest lands including, naturally, fires occurring within spotted owl territories.

Cores, PACs and CACs: For most spotted owl territories in the Southwestern Region, the Forest Service has delineated a Core area to include at least 450 acres (182 hectares) surrounding a nest site, (or, if no nest is found, to include the cluster of recorded owl detections). Recently, following the recommendations in the Mexican Spotted Owl Recovery Plan, the Forest Service expanded the Core areas to a minimum of 600 acres (243 hectares) and renamed them Protected Activity Centers (PACs).

Because each core/PAC is drawn by a local biologist to include habitat deemed most likely to be used by owls for nesting and roosting habitat, boundaries are usually irregular. Many PACs and cores are long and sinuous, encompassing steep-sloped areas within canyons, and

occasionally exclude cadastral features such as private land. For my purposes, I wanted to describe fire behavior in a consistently delineated area, namely a circle centered on the nest site or cluster of owl detections. I refer to this as a Circular Activity Center (CAC). I have delineated two sizes of CAC (a larger1-km radius CAC and a smaller 400-m radius CAC) in order to look at patterns on two different spatial scales. I also collected data on fire severity and cover type within the Forest Service-delineated PACs and Cores because these landscape units are likely to be more biologically meaningful despite their subjective delineation.

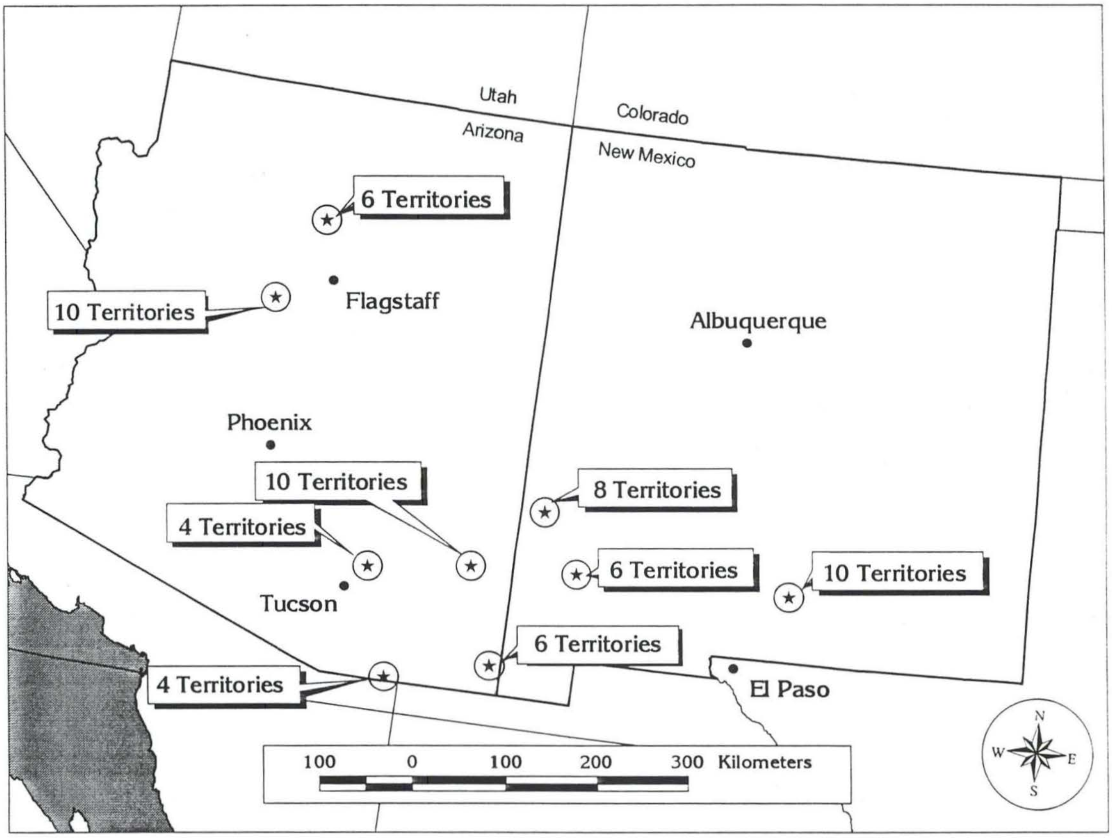
At the time of this study, not all cores had been redrawn as PACs and a few territories had not had any territory boundary delineated for them, so this study incorporates cores, PACs and CACs. In cases where the distinction between these territory delineations does not matter, this thesis will refer to all spotted owl home areas as *territories*.

With help from the Southwestern Region Forest Service biologists, Russell Duncan of Southwestern Field Biologists, and Chris May of Humboldt State University, I selected a number of territories in Arizona and New Mexico that had burned during 1993-1996 (Bieber 1996; Boucher and Pope 1996; Duncan 1996; Froehlich and McCluhan 1996; Helbing 1996; May 1996; Randall-Parker 1996; Salas 1996; Sheppard 1996; Skinner 1996). I accepted territories that had been burned by prescribed and prescribed natural fire as well as by wildfire. I then matched each burned territory with a territory that had not burned recently in order to have a set of control territories to compare to the burned territories. These unburned territories were selected primarily based on physical proximity, topographic similarity and similarity of vegetative cover type, and no burned territory was more than 12 kilometers from its unburned counterpart.

Although I intended to select 32 burned territories paired with 32 unburned territories, during the course of the surveying effort I found one of the "burned" territories had no evidence

of recent fire and two "unburned" territories had reasonably extensive burned areas within them (Loma Linda and Red Ridge territories, Appendix B, p. 97-98). This left 33 burned territories, 31 unburned territories and 29 pairs of burned/unburned territories. Sixteen of these territories were in the Coconino National Forest near Flagstaff, AZ, 24 were in the Coronado National Forest divided up among the Catalina, Pinaleno, Chiricahua and Huachuca mountain ranges, 14 were in the Gila National Forest near Reserve and Silver City, NM, and 10 territories were in the Lincoln National Forest near Cloudcroft, NM (Figure 1).

Figure 1: Distribution of Surveyed Mexican Spotted Owl Territories



As mentioned above, some of these territories had PACs delineated, some had Cores and a few had no territory boundary delineation that I could find. In all cases I created a 1-km radius CAC around either the historical nest site or the center of the cluster of historical locations, and

my surveys covered both the original Forest Service-delineated territory and the 1-km CAC. I also delineated a 400-m radius CAC centered in the 1-km CAC in order to look at trends in this smaller circle.

Owl Survey Methods

In order to maintain consistency with previous monitoring conducted by the Forest Service, I followed (with minor alterations) the established protocols laid down in the Spotted Owl Inventory and Monitoring Handbook (Spotted Owl Subcommittee of the Oregon-Washington Interagency Wildlife Committee 1988) and the Interim Directive regarding Forest Service monitoring of Mexican spotted owls in Region 3 (USDA Forest Service Region 3 1990). These owl surveys were conducted under US Fish and Wildlife Endangered Species Permit PRT-814833, held by Dr. Joseph L. Ganey and amended to include myself and six field technicians.

Essentially these protocols define the times and methods by which the inventories could be conducted. The survey guidelines I used were as follows:

1) *Field Season*: The field season could begin no earlier than March 1 and end no later than August 31.
2) *Calling Methods*: Field personnel called for owls using either their own voices or recorded spotted owl calls. They used the four-note hoot as the primary call and mixed in other types of calls for variety. Calling was conducted at night, beginning approximately one-half hour after sunset and continuing until no later than one-half hour before sunrise. Calling was discontinued in windy and stormy conditions due to increased difficulty in hearing responses and potentially lower responsiveness of owls (Forsman 1983).
3) *Survey Locations*: The monitoring was conducted by either a single person or by two people working as a crew. The crew called for owls from fixed points or while

walking a route, and the routes and points were selected so that the calls were audible over the entire territory. Generally this meant that all points in the territory were within 0.8 km (0.5 miles) from a calling point or line. Routes and calling points were selected prior to calling and flagged when necessary.

a) *Fixed calling points*: In the case of fixed calling points, crews called continuously for 10 minutes and then remained at the site for an additional 5 minutes to listen (Seamans and Olson 1991).

b) *Calling routes*: Crews called for 10 minutes at the beginning of a trail or road, then continuously called as they walked the trail or road.

c) *Leap-frog method*: If conducting a calling route along a road, crews could use the leapfrog method described by Forsman (1983), in which one caller walked while the other drove the vehicle to a point approximately 0.5 miles down the road. The second caller would then proceed on foot, leaving the vehicle behind for the first caller. The first caller, upon reaching the vehicle would then drive it approximately 0.5 miles down the road past the second caller, leave it, and proceed on foot. The two callers would continue "leap-frogging" past each other until they reached the end of the route.

4) <u>*Record keeping:*</u> Crews maintained records on any spotted owl response or lack of response for all calling points and lines in each territory, for all visits to that territory.

a) *Night Surveys:* Crews filled out the *1997 Mexican Spotted Owl Fire Study Inventory Form* (Appendix A, p. 75) during each outing, attached to an 8½ × 11 photocopied map of the territory showing calling locations and owl responses. If a spotted owl was located at night, crews recorded the date and

time the call was heard, the sex of the owl, the number of owls heard, whether the bird was a juvenile or adult, and its approximate position according to the Universal Transverse Mercator (UTM) system (Grubb and Eakle 1988).

b) *Daytime Follow-up Surveys:* If crews found a spotted owl at night, they returned to the area within 48 hours to conduct a daytime follow-up survey. Crews spent a minimum of 4 person-hours that morning searching for the owl before giving up. Upon relocating the owl, crews would conduct visual searches of the area looking for a nest or a mate. If the visual search was unsuccessful, the crew would offer mice to the owl. If the owl took the mouse and flew off, the crews would follow and occasionally find the owl giving the mouse to a mate or juveniles. The crews offered a maximum of six mice, until the owl provided some evidence of a mate. Regardless of results, the crews would fill out the *1997 Mexican Spotted Owl Fire Study Daytime Follow-Up Visit Form* (Appendix A, p. 76) detailing what they found, attached to an 8½ × 11 map of the territory showing where they searched.

c) *Nest Site Form:* If crews located a roosting or nesting owl during the daytime follow-up, they filled out the *1997 Mexican Spotted Owl Fire Study Day Roost/Nest Site Data Form* (Appendix A, p. 78) with some simple topographic and habitat questions. These data were not used in statistical analysis for this thesis but rather were provided to Forest Service biologists as a courtesy.

5) *Owl Response Level*: At the end of the field season, each territory was assigned an *Owl Response Level* based on the presence and/or reproductive activity of spotted owls on that territory. There were four possible response levels:

a) *Absence*: The owls were considered absent from the territory if no owl was

located after a minimum of 4 visits to the territory. In this case the territory was assigned an *Owl Response Level* = 1.

b) *Single*: Crews recorded at least one auditory or visual location of at least one spotted owl over the field season. If crews were unable to determine conclusively that there were both a male and female on the territory, the territory was assigned an *Owl Response Level* = 2.

c) *Pair Occupancy:* Crews recorded auditory or visual locations of both a male and a female owl within the territory. In this case the territory was assigned an *Owl Response Level* = 3.

d) *Reproduction:* Crews sighted fledgling spotted owls outside the nest. In this case the territory was assigned an *Owl Response Level* = 4.

6) <u>Complete Surveys</u>: Each territory was surveyed a minimum of 4 times unless fledgling spotted owls were observed outside the nest prior to the fourth survey. If predators such as goshawks (*Accipiter gentilis*) or great horned owls (*Bubo virginianus*) were heard in territories where the presence of spotted owls was still undetermined, calling continued but crews proceeded with caution. Consecutive territory surveys were conducted a minimum of 5 days apart.

7) <u>Paired Territories</u>: In all cases, both the burned territory and its unburned counterpart were surveyed by the same individuals. This was done in order to eliminate potential biases caused by observers with different skill levels. If the field crews had time left at the end of the season, territories were surveyed more than 4 times. In all such cases both the burned territory and its unburned counterpart were surveyed the same number of times, unless crews were able to establish early that one territory of the pair had reproducing owls.

Determining Fire Severity and Cover Type

I sampled all 33 burned territories for fire severity and dominant pre-fire vegetation type by systematically sampling a grid of points randomly overlaid on each territory map (Appendix A, p. 80). Sampling points were spaced approximately 186 m (610 ft) apart, or about 1 sampling point per 3.4 ha (8.5 ac). The 1-km radius CACs had an average of 91 survey points and the smaller 400-m radius CACs had an average of 15 survey points. The original Forest Service-delineated territories (PACs or Cores) were highly variable in size and had from 50 to 124 survey points.

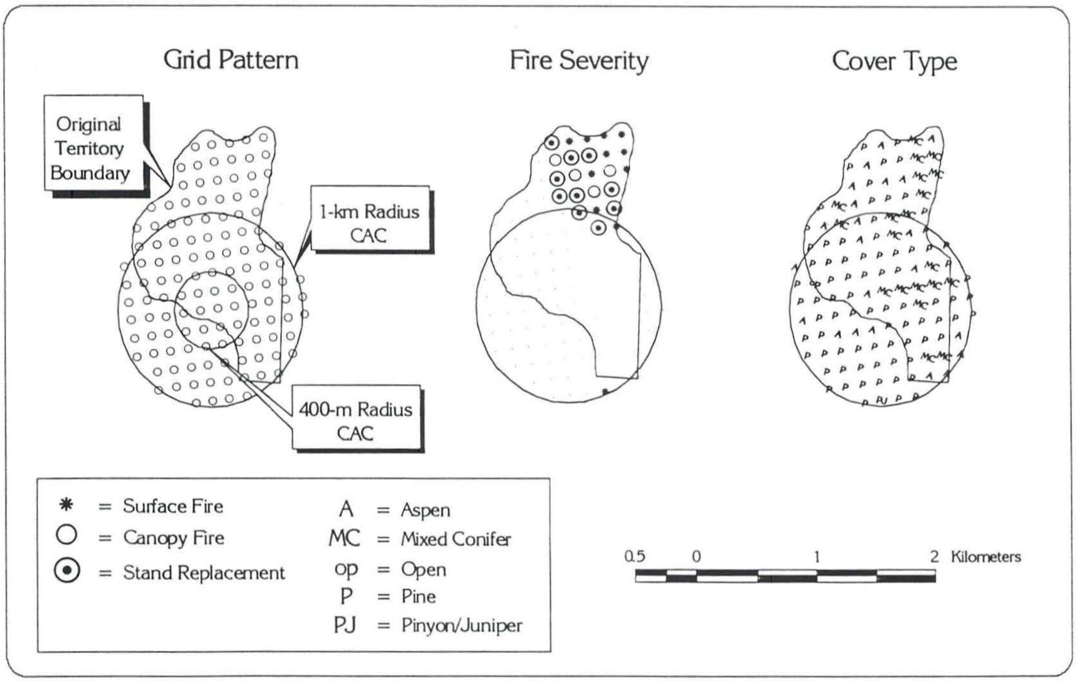
Crews paced the distance to each survey point, then surveyed a 10-m radius circle around the point for fire severity and vegetation type. If all the canopy in the circle was killed, the point was considered to have experienced stand-replacing fire. If some canopy remained alive but there was clear evidence that some canopy had burned (based on burnt crowns and snags with scorch marks along branches and trunk), the point was considered to have experienced canopy-level fire. If there was no evidence of fire in the canopy but there was evidence of ground level fire (based on scorching along the bases of trees or bare patches on the ground where the soil was obviously baked), the point was considered to have experienced surface fire. Otherwise the point was considered unburned.

Crews then determined the dominant pre-fire overstory and understory vegetation types at each survey point. They noted a variety of cover types (Appendix A, p. 79) which I aggregated into Mixed Conifer, Pine, Pine/Oak, Oak, Aspen [*Populus tremuloides*], Pinyon/Juniper, Open, Other and Unknown. Approximately 1% of my sample was Spruce or Fir and I combined these into the Mixed Conifer cover type. If the dominant overstory species was Pine and the dominant understory species was Oak, I classified the cover type as Pine/Oak. "Unknown" cover types reflect rare cases (< 2%) in which the points were inaccessible or

otherwise not surveyed, and the "Other" category reflects rare cases (< 2%) where ash [*Fraxinus* spp.], elm [*Ulmus* spp.], locust, maple, sycamore [*Platanus occidentalis*], walnut [*Juglans* spp.], willow [*Salix* spp.], or general riparian, chaparral or thornscrub species predominated. Otherwise I defined the dominant overstory species as the cover type regardless of the understory species associated with it. For statistical analysis I further collapsed these cover types into the three types I was primarily interested in (Pine, Pine/Oak and Mixed Conifer, totaling around 84% of my survey points) and classified the rest as either Other or Unknown (see *1997 Mexican Spotted Owl Cover Type and Fire Severity Inventory Form* for field data form; Appendix A, p. 79).

Figure 2 illustrates this sampling scheme and associated fire severity and cover type maps for the Hochderffer territory on the Coconino National Forest near Flagstaff, AZ. The map on the left shows the grid pattern as well as the original PAC and the 1-km and 400-m CACs.

Figure 2: Hochderffer Territory on the Coconino National Forest, showing initial grid sampling pattern and resulting *Fire Severity* and *Cover Type* maps.



Topographic Characteristics

I derived topographic characteristics of all 33 burned territories based on 7.5' Digital Elevation Models (DEMs) obtained from ALRIS (Arizona State Land Department 1997) and the USDA Forest Service Geometronics Center (1997). These DEMs break the landscape down into 30m × 30m pixels and provide an average elevation for each pixel.

Slope: Using ArcView 3.1 with the Spatial Analyst extension (ESRI 1998) I calculated the slope (in degrees) of each pixel over the landscape. Using these slope data, I calculated the average slope of each territory as well as the slope at each survey point from the Fire Severity/Cover Type grids.

Aspect: ArcView 3.1 also enabled me to calculate the aspect of each 30m × 30m pixel across the landscape. I collapsed the aspects into 4 primary directions:

1) North: 315° - 360° and 0° - 45°
2) East: 45° - 135°
3) South: 135° - 225°
4) West: 225° - 315°

I then calculated the percent of each territory that lay in each of these primary directions, as well as the primary direction of each survey point from the Fire Severity/Cover Type grids.

Topographic Roughness: I had difficulty finding an established measure for "topographic roughness" so I devised my own by making ArcView create 20m contour lines based on the DEMs, calculating the total length of these lines within the territory boundary, and then standardizing this total by dividing it by the number of hectares in the territory. The higher the total length of contour lines per hectare, the "rougher" the topography was. This measure had the advantage of being sensitive to both steepness (steeper slopes lead to more contour lines) and convoluted landscapes (high numbers of ridges and drainages lead to longer contour lines).

Summaries of individual territories, including maps, response levels and tables of topographic, vegetative and fire severity characteristics, can be found in Appendix B. Table 2 summarizes the variables I measured or calculated for each burned territory, as well as the units used in the analysis.

Table 2: Variables measured or derived for each burned territory

Variable	Units
Variables measured or derived at each survey point	
Fire Severity	Categorical, Ordinal: Range = 0 → 3
Cover Type	Categorical: 4 categories; Pine, Pine/Oak, Mixed Conifer, Other
Slope	Degrees
Aspect	Categorical: 4 categories; North, East, South, West
Elevation	Meters
X-Y Coordinates	UTM
Variables averaged over each burned territory	
Variable	**Units**
Owl Response Level	Categorical, Ordinal: Range = 1 → 4
Average Slope	Degrees
% North Aspect	% of territory
% East Aspect	% of territory
% South Aspect	% of territory
% West Aspect	% of territory
% Unburned	% of territory
% Surface Fire	% of territory
% Canopy Fire	% of territory
% Stand-Replacement Fire	% of territory
% Pine Cover Type	% of territory
% Pine/Oak Cover Type	% of territory
% Mixed Conifer	% of territory
% Other Cover Type	% of territory
Topographic Roughness	Topographic Roughness Index; range = 72 → 375

Statistical Analysis

I used a variety of parametric and nonparametric statistical tests and classification methods to answer the four research questions described on page 2. In cases where I conducted hypothesis tests, I used a type I error rate of $\alpha = 0.10$ to determine if trends were significant. In other cases I used classification techniques to determine which predictor variables had the

greatest impact on different response variables.

Research Question 1: Sign Test: In order to answer the question, "Does the presence of fire within a territory make a difference in terms of owl territory occupancy and reproductive success?", I used the *Sign Test* as described by Conover (1980) and Norušis (1998) to test the hypothesis that burned and unburned territories did not differ with respect to owl response. I used SPSS® 9.0 (SPSS 1998) to do the calculations.

The Sign test is appropriate for paired data in which the response variable (Owl Response level) is categorical and ordered (Conover 1980). The test assigns a "+" to each pair of territories in which the burned territory had a higher owl response level than the unburned territory, a "-" if the burned territory had a lower owl response level than the unburned territory, and a "0" if the response levels were tied. The test then disregards all the tie values and tests whether the number of +'s is significantly different than the number of -'s.

The assumptions of this test, as adapted from Conover (1980), are as follows:

1) Each burned/unburned pair of territories is mutually independent.
2) The measurement scale of the response variable (*Owl Response*) is at least ordinal. In other words, Owl Response can be ranked such that *absence* < *single* < *pair occupancy* < *reproduction* (see page 23).
3) The pairs are internally consistent, in that if the probability of a pair being assigned a "+" is greater than the probability of being assigned a "-", or $P(+) > P(-)$, then $P(+) > P(-)$ for all pairs. The same is true for $P(+) < P(-)$, and $P(+) = P(-)$.

I considered using a one-tailed test to see if owl response was *lower* in burned territories than in unburned territories, based on the assumption that fire in a territory would be detrimental to the owl. However, there was no conclusive evidence to support this assumption, and it seems

reasonable that in some cases fire may actually enhance the habitat (by increasing the abundance of important prey species) and, therefore, be beneficial to the owl. Furthermore, the Mexican spotted owl recovery plan points out that small-scale fires should improve owl habitat by creating canopy gaps, reducing fuel loads, thinning dense stands and reducing the threat of large-scale catastrophic fires (USDI Fish and Wildlife Service 1995). Therefore, I used a two-tailed approach to see if the owl response level was *different* in burned territories vs. unburned territories.

Because prescribed fire is an important forest management tool, it was important to minimize type II error (i.e. failing to reject the null hypothesis when fire actually did influence spotted owl presence and reproduction). Therefore, I chose $\alpha = 0.10$ and set my confidence level for my tests at 0.90.

<u>Research Questions 2 and 3: MRPP and Discriminant Analysis</u>: Research questions 2 and 3 are "Does the severity and extent of fire within a burned territory make a difference in spotted owl occupancy and reproduction" and "Do topographic characteristics or dominant cover type of a burned territory make a difference in spotted owl occupancy and reproduction". In answering these questions, I considered only the 33 burned territories. I did not compare Owl Response Levels in burned territories to Owl Response levels in unburned territories because I did not collect any habitat or topographic data in the unburned territories.

Three territory delineations: As I mentioned on page 18, I worked with three different territory boundary delineations. The original Forest Service (OFS)-delineated boundary, whether it was a Core or a PAC, was the only one drawn with known spotted owl habitat requirements in mind. This boundary was problematic, however, because a few territories had never had boundaries drawn for them, some had boundaries drawn based on different standards and were, therefore, very large, and in some cases boundaries were drawn based on factors that clearly had

nothing to do with spotted owls, such as drawing them around private land inholdings. Forest Service biologists also drew these boundaries based on widely varying amounts of information regarding whether owls were really using the territories. Some territories had many years of owl observations showing a clear territory preference while other territories had few records of observations (See Appendix B for a detailed description and history of the 33 burned territories). This Forest Service boundary delineation therefore had the advantage of being the only one drawn specifically to meet spotted owl habitat requirements, but it had the disadvantage of being highly variable in size and reliability.

The 1-km CAC drawn around the best cluster of recorded owl locations had the advantage of being a constant size and shape and thus was more appropriate for comparisons of territories and interpreting trends across territories. It has the distinct disadvantage, however, of being drawn based only on a geometric shape and positioned based on varying qualities of owl location information, and, therefore, probably bears little resemblance to the owls' preferred territory boundary.

My third territory delineation, the 400-m radius subset of the 1-km CAC, had the same advantages and disadvantages as the 1-km CAC. Analyzing all three territory delineations allowed me to determine whether a smaller, simpler design manifested the same patterns as the larger, more labor-intensive designs. The main benefits of this approach apply to simplifying future research designs.

Significance Tests: I used the Multiple Response Permutation Procedure (MRPP [Mielke and Berry 1995]) function of the *BLOSSOM* statistical package (Slauson et al. 1994) to calculate the probability that Owl Response was independent of all the fire severity, topography or habitat variables. If I found dependence, I then conducted one-way MRPP tests to identify which specific variables were associated with Owl Response. Finally, I used stepwise

discriminant function analyses to determine the most important variables and develop a simple classification model to predict Owl Response based on those variables.

The Owl Response variable was categorical and ordinal, with four levels ranging from *No Owls* to *Reproduction* (p. 23). Predictor variables were continuous, generally reflecting a percentage of the territory with some particular characteristic (percentage of territory burned at a stand-replacing level, for example).

I tested each variable for normality, in each of the three territory delineations, using the Kolmogorov-Smirnov test (Norušis 1993) (Table 3). As with other significance tests, I specified apriori a type I error rate of $\alpha = 0.10$.

Table 3 illustrates several cases in which variables failed the KS test and thus violated the assumption of normality. Because these variables were not normally distributed, parametric tests using these variables may not be appropriate or accurate (Slauson et al. 1994).

MRPP: MRPP is useful for analyzing categorical and environmental data because it uses distribution-free procedures. Rather than depending on some assumed distribution, MRPP uses permutations of the actual data to calculate the probability that the observed grouping of observations could be due to chance (Slauson et al. 1994).

MRPP is analogous to either a one-way Analysis of Variance when used with individual predictor variables, or a multivariate Analysis of Variance when used with several predictor variables simultaneously. As with ANOVA, an MRPP result can be significant when the predictor variable or variables (Table 3) vary over the four different levels of Owl Response, or when they vary in range (i.e. the variable has a much wider range in some Owl Response levels than in others).

Table 3: K-S Normality Tests of Fire Severity, Topographic and Habitat Variables in three territory boundary delineations

Variable	Kolmogorov-Smirnov Tests for Normality		
	400-m CACs	Original Forest Service (OFS) Delineations	1-km CACs
Average Slope in Degrees	0.874	0.421	0.719
Percent North-Facing Slope	0.464	0.867	1.000
Percent East-Facing Slope	0.422	0.991	0.972
Percent South-Facing Slope	0.753	0.407	0.836
Percent West-Facing Slope	0.895	0.764	0.562
Percent Unburned	0.295	0.584	0.682
Percent Surface Fire	0.695	0.753	0.779
Percent Canopy Fire	**0.081**	**0.070**	0.239
Percent Stand Replacement Fire	**0.009**	0.230	**0.081**
Percent Pine	0.403	0.452	0.648
Percent Pine/Oak	**0.045**	0.178	0.243
Percent Mixed Conifer	**0.084**	0.201	0.341
Topographic Roughness	0.666	0.335	0.528

Bold-faced items reflect cases where the variable fails the KS Test for Normality at $\alpha = 0.10$.

MRPP calculates exact probabilities when sample sizes are small but computer processing time rises to prohibitive levels when sample sizes rise above around 25. I used approximations of the exact tests for my data set of 33 burned territories. Slauson et al. (1994) point out that this approximation comes very close to the true distribution of data with sample sizes as high as mine.

My null hypothesis for the MRPP tests was that the fire severity, topographic and habitat variables had no influence on the Owl Response level of the territory. My research hypotheses were that the variables being tested did influence the Owl Response level. As with the sign test, I used an α-level = 0.10 as my cutoff level for significance.

Bonferroni Correction: I adjusted the *family-wise error* (FWE) rate of $\alpha = 0.10$ for individual tests with a Bonferroni correction (Neter et al. 1990). With 13 significance tests in each territory delineation, each individual test must have a probability level less than $\alpha = \frac{0.10}{13} = .00769$ in order to be considered significant.

Spearman's Rho Correlations: All univariate tests (e.g. MRPP, ANOVA) may attribute significance to a variable solely because it is correlated with another truly important variable (or set of variables). Because the four aspect variables and the four fire severity variables each sum to 100%, negative correlations necessarily exist within each group of variables. The three cover type variables do not sum to 100% because I do not use the *Other* category in this analysis, but there may be correlations simply because a higher percentage of one cover type means there is less room available for the others. In addition, correlations among all 13 cover type, topographic, and fire severity variables can confound interpretation of results of a particular variable. Therefore, I computed Spearman's Rho Correlation Coefficients to examine correlations among pairs of independent variables. By using ranks, Spearman's Rho is less sensitive to outliers and non-normal distributions than Pearson's *r*.

Stepwise Discriminant Analysis: After I used MRPP to get initial estimates of which variables were most highly associated with Owl Response, I then used the SPSS stepwise discriminant analysis function (SPSS 1998) to identify a smaller, more meaningful group of variables and to develop some simple classification models. A series of one-way MRPPs will attribute statistical significance to mechanistically irrelevant variables that happen to be highly correlated with important independent variables. Stepwise discriminant analysis will only select variables that significantly increase the ability of the model to discriminate between Owl Response levels, and a variable that is highly correlated with a variable already selected for the model will typically be excluded from the model because it does not add anything to the model. Discriminant analysis is an appropriate tool to use for selecting which variables most influence a categorical response variable such as my Owl Response levels.

I selected the *Wilks' lambda* statistic as my basis for stepwise selection. Wilks' lambda is the ratio between the predictor variable within-groups sum of squares and the overall sum of

squares and represents the proportion of variance that is not explained by differences in that predictor variable over Owl Response levels. Wilks' lambda values close to *1* indicate that large proportions of the variance are not explained by that predictor variable. SPSS uses the F-statistic and associated probability level for each Wilks' lambda in the stepwise selection procedure.

In the stepwise procedure, SPSS selects the predictor variable with the lowest Wilks' lambda p-value (below a user-defined threshold for entry), recalculates new Wilks' lambda values for each of the remaining variables, and then adds the next variable that meets the criteria. If including a new variable increases the significance level of any of the existing model variables above the threshold for retention, that existing model variable is removed from the model and Wilks' lambda values are recalculated. This continues until none of the remaining variables meets the minimum requirements for inclusion into the model, and all of the model variables meet the minimum requirements for retention in the model. I set the minimum probability level for entry into the model at $\alpha = 0.10$ and the minimum level for retention in the model at $\alpha = 0.20$.

Once all model variables are selected, SPSS calculates classification function coefficients for each variable. These variable coefficients allow new owl territories to be classified into one of the four Owl Response levels. SPSS tests the validity of the model by calculating the classification coefficients based on all the owl territories but one and then classifying that excluded territory, repeating this process until all territories are classified.

Discriminant Analysis Assumptions: Discriminant analysis assumes that the data are normally distributed, the variances of the variables are equal between each Owl Response level, that all variables combined follow a multivariate normal distribution, and that covariances between variables are equal between each Owl Response level.

Six variables were not normally distributed (Table 3). Square-root transformation of three of these (*% Mixed Conifer* from the 400-m CACs, *% Canopy Fire* from the OFS territories,

and *% Stand Replacement Fire* from the 1-km CACs) produced normally distributed variables (Table 4). However, I was unable to significantly improve the normality of three of the variables that were not normally distributed in the 400-m CACs (*% Canopy Fire*, *% Stand Replacement Fire*, and *% Pine/Oak*) because large proportions of the 400-m CACs had values of *0* for these variables (i.e. there was no canopy fire, stand replacement fire or pine/oak forest in many of the 400-m CACs). Therefore, my discriminant analysis on the 400-m CACs violates the assumption of normality and multivariate normality, and significance levels calculated in this analysis will likely be inaccurate. Inaccurate significance levels might cause variables to be included in or rejected from the model erroneously.

Table 4: K-S Normality Tests of Fire Severity, Topographic and Habitat Variables, in three territory boundary delineations, following Square-Root transformations in 3 variables

Variable	Kolmogorov-Smirnov Tests for Normality		
	400-m CACs	Original Forest Service (OFS) Delineations	1-km CACs
Average Slope in Degrees	0.874	0.421	0.719
Percent North-Facing Slope	0.464	0.867	1.000
Percent East-Facing Slope	0.422	0.991	0.972
Percent South-Facing Slope	0.753	0.407	0.836
Percent West-Facing Slope	0.895	0.764	0.562
Percent Unburned	0.295	0.584	0.682
Percent Surface Fire	0.695	0.753	0.779
Percent Canopy Fire	**0.081**	0.663*	0.239
Percent Stand Replacement Fire	**0.009**	0.230	0.284*
Percent Pine	0.403	0.452	0.648
Percent Pine/Oak	**0.045**	0.178	0.243
Percent Mixed Conifer	0.309*	0.201	0.341
Topographic Roughness	0.666	0.335	0.528

* Transformed by taking square root of original data
Bold-faced items reflect cases where the variable fails the KS Test for Normality at $\alpha = 0.10$.

Although *Box's M* test is sometimes viewed with apprehension because it is highly sensitive to mild departures from multivariate normality (SPSS 1999), it is the only test SPSS offered to test for equal covariances. Both the 400-m CACs and the 1-km CACs met the

assumption of equal covariances, but variables in the OFS territories failed the test of equal covariances (Table 5).

Table 5: *Box's M* tests of equal covariances of all predictor variables among the four levels of Owl Response

Territory Delineation	Box's M	Approx. *F*	df1	df2	Significance
400-m CACs	19.827[a]	1.352	12	1926.836	0.182
OFS territories	28.455[a]	1.940	12	1926.836	0.026[b]
1-km CACs	14.517	1.257	9	420.672	0.258

[a] SPSS calculated that there were so few cases of the *Reproduction* Owl Response Level that variables in the 400-m CACs and the OFS territories formed a "singular matrix" which could not be compared with the covariance matrices in the other three Owl Response levels. Therefore, for the 400-m CACs and the OFS territories, SPSS used the *Box's M* statistic to compare covariance matrices only between the *No Owls, Single Owls* and *Pairs* levels of Owl Response.

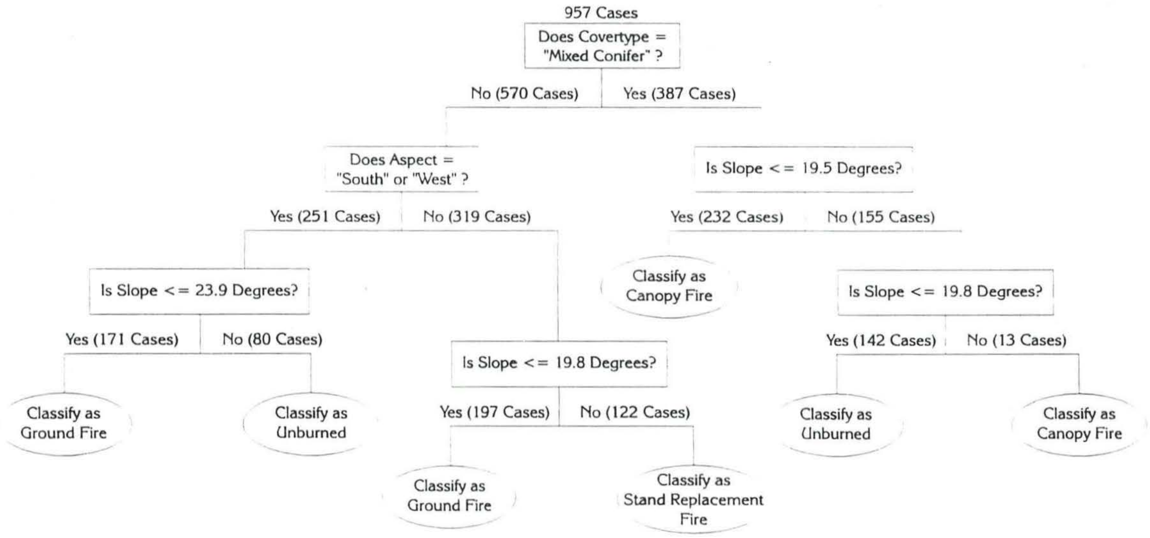
[b] Significant at $\alpha = 0.10$. Therefore Reject assumption of equal covariances.

Research Question 4: CART: Research question 4 is "Do the topographic characteristics (i.e. slope and aspect) or the dominant vegetative cover type influence the pattern of burn within spotted owl territories?" I used the CART (Classification And Regression Tree) statistical analysis program (Breiman et al. 1994) to build classification models for each of the three territory delineations based on the three topographic and vegetative characteristics I had for each survey point. CART uses a binary decision tree system in which the data set is split into two smaller data sets based on the value of one of the predictor variables (*Slope, Aspect* or *Cover Type*). For example, if CART found that *Slope* was the variable most highly associated with Fire Severity, and then found that points with slopes above 30° always burned at stand replacing levels, CART would then split the data set into two subsets based on values of *Slope* either greater than or less than 30°. CART would then look at each subset of data independently and repeat this data splitting process until some prespecified criteria had been met, at which point each final subset of data would be classified at one of the four Fire Severity levels. The final model, called a classification tree, is then checked for predictive accuracy using a cross-validation technique in which CART randomly divides the original data set into 10 subsets, rebuilds the model using 9 of these subsets, and then classifies all points in the 10th subset based

on that model. CART then repeats the process 10 times so that each subset has been classified based on a model developed from all subsets except that one (Steinburg and Colla 1994; Steinburg and Colla 1992). This method allows CART to estimate overall predictive accuracy as well as predictive accuracies at each Fire Severity level.

Classification trees can be very effective tools for classifying data with categorical and continuous predictor variables into a categorical response variable (Verbyla 1987), provided you have enough cases and you use the right predictor variables. Figure 3 illustrates one classification tree in which 957 initial survey points were classified into Fire Severity levels. In this particular tree, cross-validation yielded an overall predictive accuracy of 35%, with individual Fire Response level accuracies of 35% for *Unburned*, 43% for *Surface Fire*, 52% for *Canopy Fire*, and 25% for *Stand Replacement Fire*.

Figure 3: Example of a CART Classification Tree illustrating the classification of 957 survey points into four Fire Severity levels based on *Slope, Aspect* and *Cover Type*.



The three predictor variables I used (*Slope, Aspect* and *Cover Type*) were not sufficient to accurately predict fire severity. Fire severity prediction models that do not include fuel and climate variables, which I did not have available to me, should be viewed with great caution.

Also, my survey points were not independent samples. The fire severity at any particular survey point was almost certainly highly influenced by the fire severity at nearby points. Because of these problems my CART analyses had low power to detect true relationships.

RESULTS

Comparison of Burned and Unburned Territories

Unburned territories had slightly more cases of "Pairs" and "Reproduction" than burned territories while burned territories had twice as many cases of "No Owls" and slightly more cases of "Single Owls" than unburned territories (Table 6). According to the sign test, those differences were not significant ($P = 0.115$; Table 7).

Table 6: Response level of each burned territory and paired control territory.

Forest	Burned Territory Name	No Owls	Single	Pair	Reproduction	Control (Unburned) Territory Name	No Owls	Single	Pair	Reproduction
Coconino	Secret Canyon			X		West Buzzard Point			X	
	Secret Mountain	X				Barney Springs		X		
	Secret Cabin			X		Hidden Cabin		X		
	East Bear Jaw	X				Weatherford			X	
	Hochderffer	X				Little Spring		X		
	Red Hill	X				Bunker Hill	X			
	Upper West Fork			X		Rattlesnake	X			
	Orion Springs			X		Pipeline			X	
Coronado (Chiricahuas)	Rattlesnake Peak	X				Barfoot		X		
	Rucker Canyon		X			Dobson Peak			X	
	Mormon Canyon			X		Sunny Flat	X			
Coronado (Catalinas)	Shovel Springs		X							
	Red Ridge			X						
	Romero Canyon			X						
	Loma Linda		X							
Coronado (Huachucas)	Miller Canyon			X		Ramsey Canyon			X	
	Hunter Canyon		X			Lower Ash Canyon			X	
Coronado (Pinalenos)	Riggs Lake				X	Grant Hill			X	
	Webb Peak				X	Lefthand Canyon		X		
	Upper Cunningham			X		Hagens Point			X	

Table 6: Response level of each burned territory and paired control territory.

Forest	Burned Territory Name	No Owls	Single	Pair	Reproduction	Control (Unburned) Territory Name	No Owls	Single	Pair	Reproduction
Coronado (Pinalenos) (*cont.*)	Mill Site	X				Ash Creek				X
						Turkey Flat[2]			X	
						Pitchfork Canyon	X			
Gila	Tadpole #1		X[3]			Redstone #1			X	
	Tadpole #2			X		Redstone #3			X	
	Tadpole #3		X			McMillen				X
	Juniper Saddle			X		Deep Canyon			X	
	Piney Park	X				Bear Canyon			X	
	Gila Woods	X				McCarty			X	
	Wilson			X		White Rocks			X	
Lincoln	Circle Cross		X			Carissa				X
	Bridge				X	Danley				X
	Scott Able			X		Jeffers	X			
	Carr	X				Walker			X[4]	X[4]
	Fire	X				Sixteen Springs			X	
Totals		**10**	**7**	**13**	**3**		**5**	**5**	**17**	**5**

[1] The *Red Ridge* and *Loma Linda* territories were originally considered Control territories, but our surveys turned up evidence of recent fire and they were reclassified as Burned territories. This left *Romero Canyon* and *Shovel Springs* without a paired unburned territory.

[2] The *Turkey Flat* territory was originally considered a burned territory, but our survey points turned up no evidence of fire within the boundaries. *Turkey Flat* was reclassified as an unburned territory.

[3] Both a male and female were found at *Tadpole #1*, but the male was approximately 800m west of the territory boundary and therefore this territory was classified as Single.

[4] Two pairs found at *Walker*, one with evidence of reproduction. Walker was therefore classified as Reproductive.

Table 7: Frequencies and significance level of sign test, measuring *Response Level of Unburned Territory - Response Level of Paired Burned Territory.*

Total Number of Pairs	Negative Differences (-)[a]	Positive Differences (+)[b]	Ties (0)[c]	Exact Significance Level (2-tailed)
29	6	14	9	0.115[d]

[a] Response Level of Burned territory > Response of paired unburned territory

[b] Response Level of Burned territory < Response of paired unburned territory

[c] Response Level of Burned territory = Response of paired unburned territory; not included in the analysis

[d] Binomial distribution used

Eight of the 33 burned territories burned in 1996, one year prior to my study. Of these, only 2 territories (25%) had no owls. Of the 25 territories that burned 2-4 years prior to my study, 8 territories (32%) had no owls.

Influence of Fire Severity, Topographic and Habitat Variables on Owl Response

The overall MRPP test indicated that owl response was influenced by some variable or combination of variables (Table 8) in all three territory delineations.

Table 8: MRPP Results for three territory boundary delineations

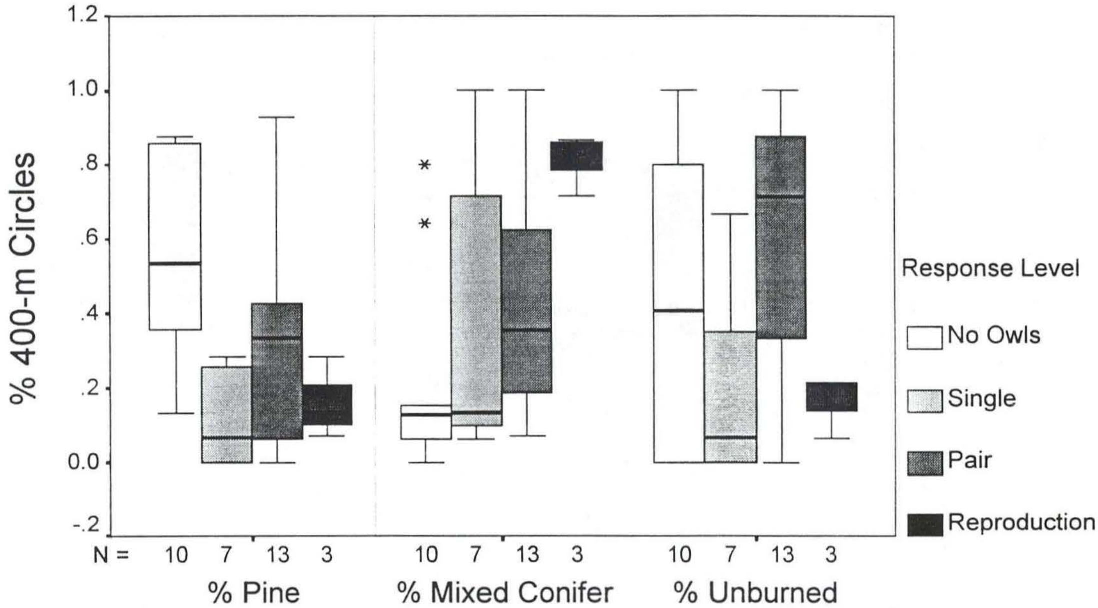
Variables	Probability of a smaller or equal delta		
	400-m Radius CAC	Original Forest Service (OFS) Delineation	1-km Radius CAC
All Predictor Variables Analyzed Simultaneously	0.015*	0.010*	0.040*
Average Slope in Degrees	0.246	0.009*	0.524
% North-facing slope	0.617	0.056*	0.224
% East-facing slope	0.191	0.609	0.716
% South-facing slope	0.560	0.236	0.103
% West-facing slope	0.679	0.735	0.923
% Unburned	0.046*	0.191	0.075*
% Ground Fire	0.868	0.744	0.712
% Canopy Fire	0.233	0.773	0.178
% Stand Replacement Fire	0.253	0.081*	0.263
% Pine	0.007**	0.007**	0.003**
% Pine/Oak	0.219	0.228	0.226
% Mixed Conifer	0.025*	0.073*	0.038*
Topographic Roughness	0.219	0.009*	0.597

* Significant at $\alpha = 0.10$ level
** Significant at Family-Wise Error rate of $\alpha = 0.10$, or Bonferroni-adjusted $\alpha = 0.00769$.

Subsequent tests revealed that three variables were significant at $\alpha = 0.10$ in the 400-m CACs, six variables within the OFS territories, and three were significant in the 1-km CACs (Table 8).

<u>400-m CACs</u>: Three variables (*% Unburned, % Pine* and *% Mixed Conifer*) were significant at $\alpha = 0.10$. Only *% Pine* remained significant after applying the Bonferroni correction. To illustrate trends in the data and show how the variables change over Owl Response levels, I developed boxplots of each of the three variables that were significant at $\alpha = 0.10$ (Figure 4).

Figure 4: Distribution of three predictor variables in 400-m CACs within each Owl Response level. Horizontal bars within boxes represent the median of the data, the tops and bottoms of the boxes represent the 75th and 25th quantiles of the data, and the whiskers represent the smallest and largest data points lying within 1.5 box lengths. Outlying data are displayed with the symbol "o" and represent data points between 1.5 and 3 box lengths from the box. Extreme outliers are displayed with the symbol "*" and represent data points greater than 3 box lengths from the edge of the box (Norušis1998).



Because only three territories had confirmed reproduction, inferences about outliers, range or skewness of variables in reproductive territories should be treated cautiously.

% Pine, the only variable also significant at the Bonferroni adjusted α-level, is easiest to interpret. Those territories where I found owls, either singly, in pairs or with young, tended to have lower percentages of pine than those territories where I did not find owls. I tended not to find owls in those territories that had the highest rates of *% Pine*.

% Mixed Conifer appeared to be highest in those territories with successful reproduction and relatively low in territories with no owls. This is consistent with spotted owl preferences for mixed conifer over pure pine stands (Ganey and Dick 1995). The percentage of mixed conifer had a larger variance in territories with single owls or pairs of owls than in territories with no owls or with reproducing owls. Recall that in MRPP a variable is considered significant based on either different means or different variances among owl response levels. *% Mixed Conifer*

manifested a strong negative correlation with *% Pine* (Table 9) and perhaps its significant *p*-value is due solely to this correlation.

% Unburned manifested relatively high rates of unburned survey points in those territories that had either pairs of owls or no owls, and relatively low rates in those territories that had either a single owl or confirmed reproduction. This pattern is difficult to explain biologically. If *% Unburned* were truly a determining factor for Owl Response, then rates of *% Unburned* in territories with pairs of owls should be more similar to rates of *% Unburned* in territories with either single or reproducing owls than to territories with no owls. This anomaly cannot be explained by correlation of this variable with other more important factors, as *% Unburned* was not correlated with either *% Pine* or *% Mixed Conifer* (Table 9).

The stepwise discriminant procedures produced a classification model using the variables *% Pine*, *% Unburned* and *% East Facing Slope* (Table 10). *% Mixed Conifer* was not selected, apparently because it did not add discrimination power to a model that included *% Pine*. The final Wilks' Lambda value for the model (0.325) indicates that 32.5% of the variation between Owl Response levels is not accounted for in this model. When viewed alone, *% East-Facing Slope* does not show any clear association with Owl Response (Figure 5)

The model itself consists of a set of classification coefficients (Table11) which can be used to classify new territories based on the percentages of pine, unburned areas and east-facing slopes within those territories. A new territory is predicted to have the Owl Response level corresponding to the highest score.

Using the cross-validation procedures, this model correctly classified territories into the correct Owl Response level 57.6% of the time (Table 12). Pure chance should give us a predictive accuracy of 25% for these four Owl Response levels.

Significantly, this model never accurately predicted if a territory would be reproductive, but I found reproduction in only 3 burned territories. The model classified those territories with no owls, single owls, or pairs with reasonable accuracy (60%, 57% and 69%, respectively).

Table 9: Spearman's Rho Correlations - 400m CACs: The upper right portion of this table represents the Spearman's Rho Correlation Coefficients for each pair of variables, and the lower left portion of the table represents the significance level of that correlation.

	Slope	% North	% East	% South	% West	% Unburned	% Ground Fire	% Canopy Fire	% Stand-Replacement Fire	% Pine	% Pine/Oak	% Mixed Conifer	Topographic Roughness
Average Slope		.181	.039	-.198	-.055	.017	.112	.058	-.011	-.489**	.192	.158	.998**
% North	.314		-.032	-.611**	-.400*	-.309	.572**	.154	.128	.177	.513**	-.288	.190
% East	.827	.861		-.097	-.623**	.140	-.016	-.248	-.201	-.228	.250	-.097	.026
% South	.269	.000**	.592		-.018	.156	-.576**	-.105	.178	-.023	-.371*	.220	-.199
% West	.759	.021*	.000**	.919		-.063	.075	.218	-.079	.131	-.247	.047	-.059
% Unburned	.924	.081	.436	.387	.728		-.494**	-.784**	-.736**	-.115	-.241	.171	.028
% Ground Fire	.536	.000**	.928	.000**	.680	.004**		.380*	.015	.081	.462**	-.162	.107
% Canopy Fire	.750	.392	.163	.559	.223	.000**	.029*		.602**	-.047	-.036	.158	.053
% Stand-Replacement Fire	.953	.477	.261	.321	.663	.000**	.933	.000**		.003	.073	.010	-.013
% Pine	.004**	.323	.202	.900	.467	.523	.656	.797	.988		-.048	-.630**	-.476**
% Pine/Oak	.283	.002**	.161	.033*	.166	.177	.007**	.842	.686	.790		-.463**	.188
% Mixed Conifer	.381	.105	.590	.219	.797	.340	.368	.381	.956	.000**	.007**		.151
Topographic Roughness	.000**	.289	.887	.268	.742	.876	.552	.769	.943	.005**	.294	.401	

Correlation

*Significance Level (2-tailed)****

* *Correlation is significant at the 0.05 level (2-tailed).*

** *Correlation is significant at the 0.01 level (2-tailed).*

*** *Due to the high number of correlations represented here, some correlations may be significant only because of random chance.*

Table 10: Steps in stepwise discriminant analysis classification model development for 400-m CACs, OFS territories and 1-km CACs, with variables included at each step and corresponding model Wilks' Lambda and *F*-statistics.

Model	Step	Model Variables [a]	Overall Model Wilks' Lambda[b]	F Statistic	df1	df2	Sig.
400-m CAC	1	*%Pine*	.659	5.009	3	29	.006
	2	*%Pine + % Unburned*	.457	4.476	6	56	.001
	3	*%Pine + % Unburned + % East-Facing Slope*	.325	4.289[c]	9	65.9	.000
OFS	1	*% Pine*	.693	4.289	3	29	.013
	2	*% Pine + Average Slope*	.539	3.374	6	56	.007
	3	*% Pine + Average Slope + % Stand Replacement Fire*	.424	3.098[c]	9	65.9	.004
1-km CAC	1	*% Pine*	.626	5.783	3	29	.003
	2	*% Pine + % Unburned*	.455	4.510	6	56	.001

[a] At each step, the variable that minimizes the overall Wilks' Lambda is entered. The *F*-statistic of that variable must have a significance level ≤ 0.10 for it to be included in the model. Once in the model, that variable must maintain a significance level ≤ 0.20 to be retained in the model.

[b] Wilks' Lambda tests how well the model separates the different Owl Response levels. Low values indicate strong group differences.

[c] SPSS calculated an approximate *F*-statistic rather than an exact *F*-statistic at step 3 of this model.

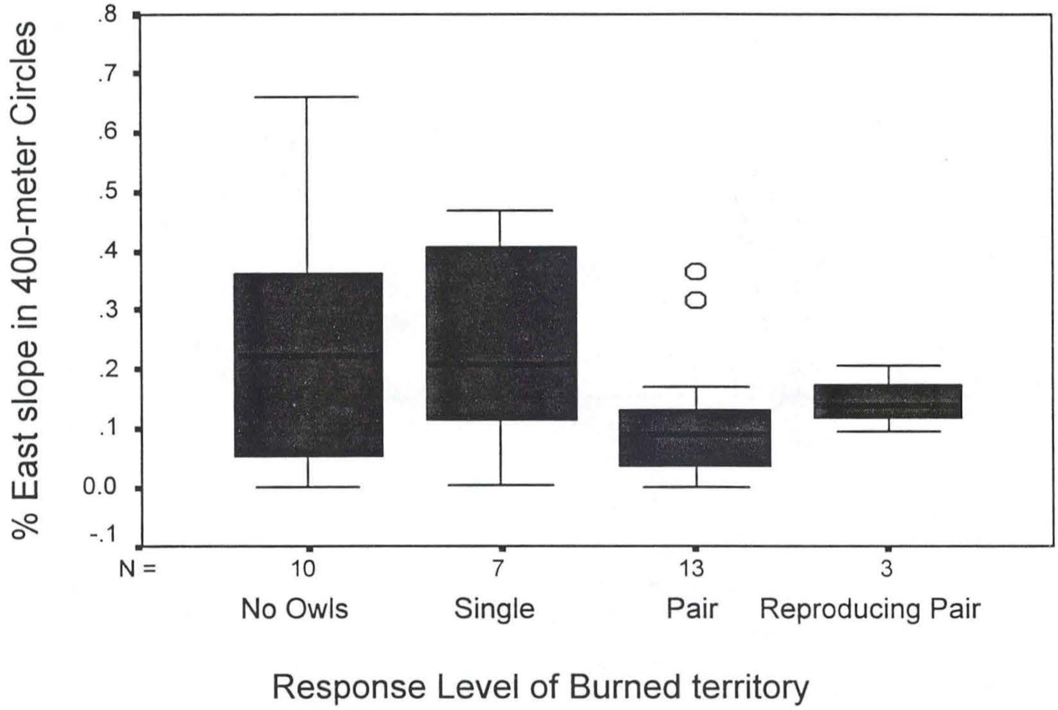
Table 11: Classification Function Coefficients for 400-m CACs

Model Variable	Owl Response Level: No Owls	Single Owl	Pair	Reproduction
% Pine	15.931	12.459	5.424	8.249
% Unburned	4.451	.765	6.422	1.168
% East-Facing Slope	16.647	6.357	10.343	5.927
(Constant)	-8.720	-3.556	-4.844	-3.588

Table 12: 400-m CACs - Cross Validations and Predictive Accuracy of Discriminant Analysis Model, where each territory is classified by classification functions derived from all territories other than that territory

	Response Level	No Owls	Single	Pair	Reproducing Pair	Total
Count	No Owls	6	2	2	0	10
	Single	1	4	0	2	7
	Pair	3	1	9	0	13
	Reproducing Pair	0	3	0	0	3
%	No Owls	60%	20%	20%	0%	100%
	Single	14%	57%	0%	29%	100%
	Pair	23%	8%	69%	0%	100%
	Reproducing Pair	0%	100%	0%	0%	100%

Figure 5: Boxplots of *% East-Facing Slope* in 400-m CACs, demonstrating distribution of data within each Owl Response level. Horizontal bars within boxes represent the median of the data, the tops and bottoms of the boxes represent the 75th and 25th quantiles of the data, and the whiskers represent the smallest and largest data points lying within 1.5 box lengths. Outlying data are displayed with the symbol "o" and represent data points between 1.5 and 3 box lengths from the box. Extreme outliers are displayed with the symbol "*" and represent data points greater than 3 box lengths from the edge of the box (Norušis 1998).

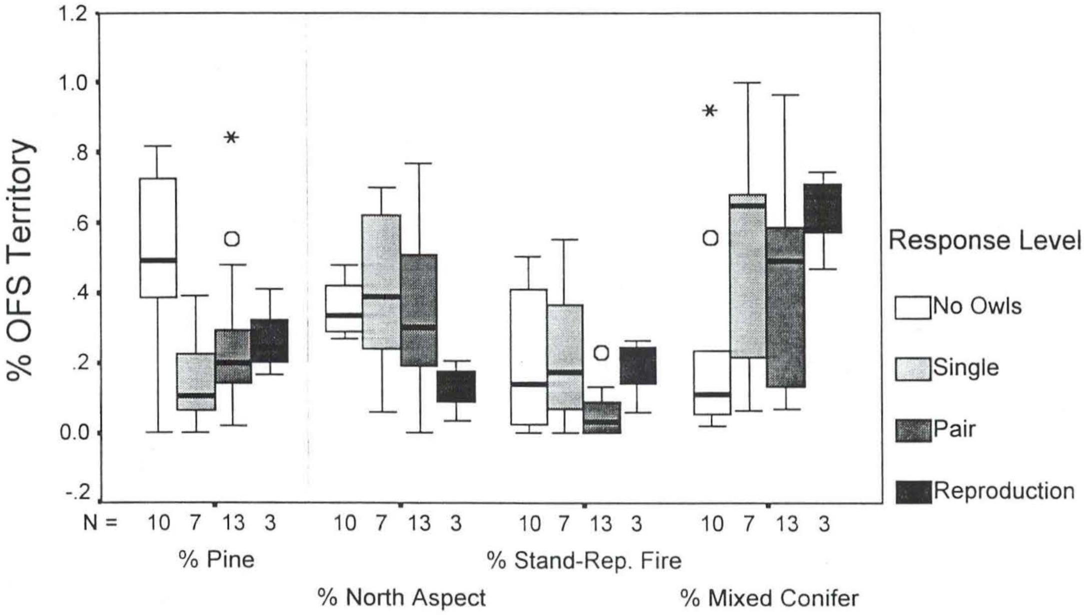


OFS territories: Within the Original Forest Service-delineated boundaries, six variables differed among owl response classes in univariate MRPP (Table 8). Of these six, only *% Pine* was significant after applying the Bonferroni correction. Boxplots help to illustrate why these six variables were significant (Figures 6 and 7).

% Pine, the only variable significant at the Bonferroni adjusted α-level, offered the clearest interpretation. As I found in the 400-m CACs, I tended to have much higher levels of *% Pine* in those territories where I did not find owls. *% Pine* was fairly constant and relatively low in territories with single owls, pairs or reproducing pairs.

The significance of *% North* may be due to low variance in territories with either no owls or reproducing owls. Significance in *% Stand Replacing Fire* may be based on the relatively low percentages of stand-replacing fire in those territories with pairs of owls.

Figure 6: Boxplots of *% North Aspect, % Stand-Replacing Fire, % Pine* and *% Mixed Conifer* predictor variables in OFS territories, demonstrating distribution of variable data within each Owl Response level. Horizontal bars within boxes represent the median of the data, the tops and bottoms of the boxes represent the 75th and 25th quantiles of the data, and the whiskers represent the smallest and largest data points lying within 1.5 box lengths. Outlying data are displayed with the symbol "o" and represent data points between 1.5 and 3 box lengths from the box. Extreme outliers are displayed with the symbol "*" and represent data points greater than 3 box lengths from the edge of the box (Norušis 1998).

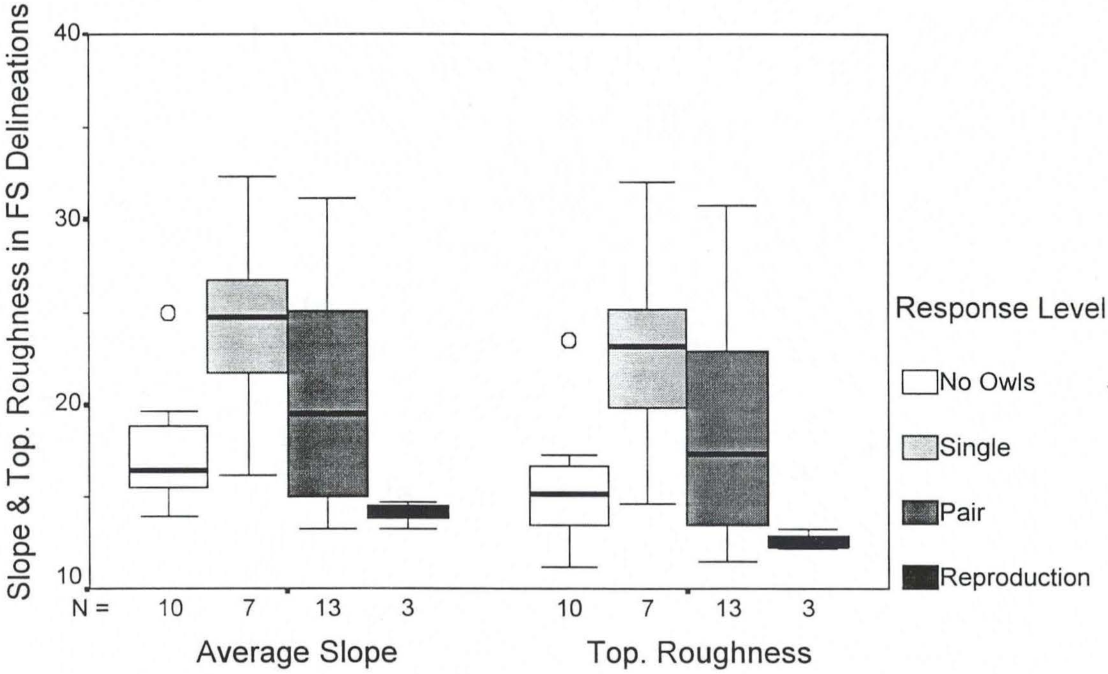


% Mixed Conifer shows a reasonably clear trend, with percentages of mixed conifer tending to increase as Owl Response increased. Territories with no owls tended to have lower percentages of mixed conifer, although there is a lot of overlap between the Owl Response Levels.

Average Slope and *Topographic Roughness* follow nearly identical trends (Figure 7), reflecting the high correlation between them (Spearman's Rho = 0.992, Table 13). Both tend to be relatively high in cases where there are single owls and relatively low in cases where there are either no owls or reproducing owls. The biological interpretation of this pattern is unclear. Several strong correlations between the six significant variables (Table 13) justifed pursuing more sophisticated discriminant analyses on the data.

All transformed variables in the OFS territories met the *Kolmogorov-Smirnov* test for

Figure 7: Boxplots of *Average Slope* and *Topographic Roughness Index* predictor variables in OFS territories, demonstrating distribution of variable data within each Owl Response level. The *Topographic Roughness* index has been scaled to the same units as *Average Slope*. Horizontal bars within boxes represent the median of the data, the tops and bottoms of the boxes represent the 75th and 25th quantiles of the data, and the whiskers represent the smallest and largest data points lying within 1.5 box lengths. Outlying data are displayed with the symbol "o" and represent data points between 1.5 and 3 box lengths from the box (Norušis 1998).



normality, but this set of variables failed the *Box's M* test of equal variances. My discriminant function classification model used the variables *% Pine*, *% Stand Replacing Fire* and *Average Slope* (Tables 10 and 14). *% Pine* was the most influential variable. The final Wilks' Lambda value for the model (Wilks' Lambda = 0.424) indicates that 42.4% of the variation between Owl Response levels was not accounted for in this model.

The cross-validated classification success rate of this model (45.5%; Table 15) was somewhat less than that of the 400-m CACs model, but still much better than random chance. As with the 400-m CACs, this model never correctly classified a reproducing territory. The model also did relatively poorly at classifying territories with single owls (29% success rate), but it did relatively well at classifying territories with either no owls or with pairs of owls (60% and 54% respectively).

Table 13: Spearman's Rho Correlations - OFS territories. The upper right portion of this table represents the Spearman's Rho Correlation Coefficients for each pair of variables, and the lower left portion of the table represents the significance level of that correlation.

	Slope	% North	% East	% South	% West	% Unburned	% Ground Fire	% Canopy Fire	% Stand-Replacement Fire	% Pine	% Pine/Oak	% Mixed Conifer	Topographic Roughness
Average Slope		.316	-.002	-.340	.072	.111	-.109	-.010	-.064	-.392*	.200	.147	.992**
% North	.073		-.002	-.699**	-.448**	-.278	.653**	.116	.036	.022	.336	-.160	.314
% East	.990	.991		-.231	-.447**	.144	-.002	-.349*	-.043	-.264	.006	.018	-.002
% South	.053	.000**	.195		-.020	.258	-.564**	-.137	-.004	.054	-.160	-.131	-.340
% West	.690	.009**	.009**	.914		.059	-.255	.143	-.025	.180	-.209	.215	.074
% Unburned	.540	.118	.425	.148	.746		-.582**	-.865**	-.792**	-.204	.031	.018	.106
% Ground Fire	.545	.000**	.990	.001**	.153	.000**		.384*	.243	.251	.278	-.193	-.102
% Canopy Fire	.956	.520	.047*	.448	.429	.000**	.028*		.627**	.132	-.211	.173	-.027
% Stand-Replacement Fire	.722	.841	.812	.983	.890	.000**	.173	.000**		.089	-.149	.087	-.066
% Pine	.024*	.905	.138	.765	.317	.255	.159	.462	.621		.210	-.690**	-.397*
% Pine/Oak	.264	.056	.973	.372	.242	.866	.117	.238	.408	.241		-.589**	.241
% Mixed Conifer	.413	.373	.922	.467	.230	.921	.283	.335	.630	.000**	.000**		.133
Topographic Roughness	.000	.076	.993	.053	.683	.556	.572	.883	.717	.022*	.178	.461	

Correlation

*Significance Level (2-tailed)****

* *Correlation is significant at the 0.05 level (2-tailed).*

** *Correlation is significant at the 0.01 level (2-tailed).*

*** *Due to the high number of correlations represented here, some correlations may be significant only because of random chance.*

Table 14: Classification Function Coefficients for OFS territories				
Model Variable	**Owl Response Level**			
	No Owls	**Single Owl**	**Pair**	**Reproduction**
% Pine	16.729	10.054	12.218	10.203
% Stand Replacement Fire	12.464	15.137	7.026	10.744
Average Slope	.962	1.174	1.012	.745
(Constant)	-15.150	-18.322	-13.316	-10.039

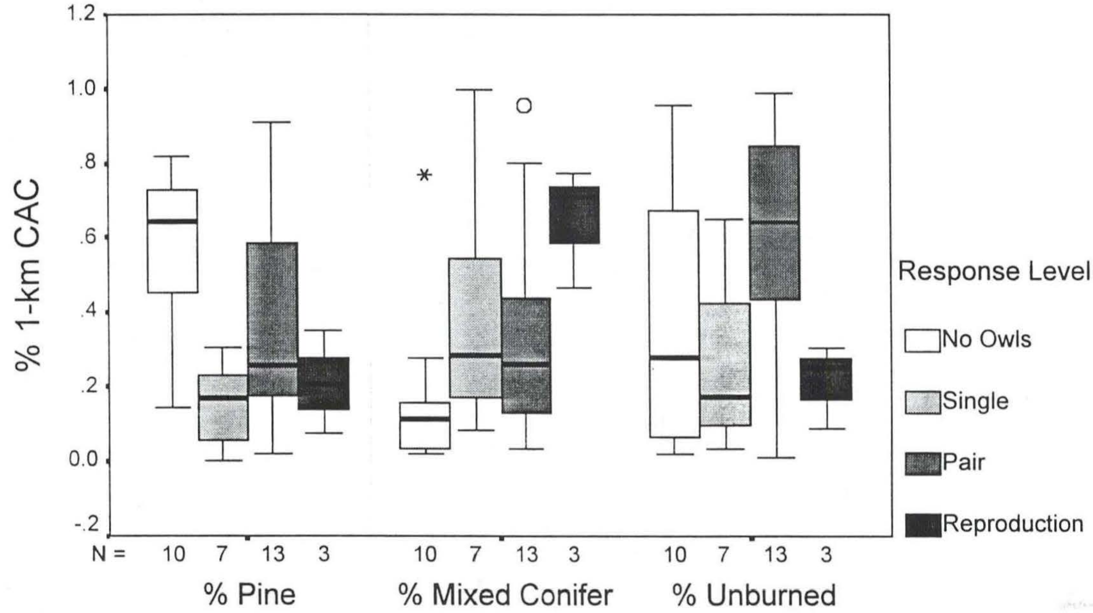
Table 15: OFS territories - Cross Validations and Predictive Accuracy of Discriminant Analysis Model, where each territory is classified by classification functions derived from all territories other than that territory

	Response Level	**No Owls**	**Single**	**Pair**	**Reproducing Pair**	**Total**
Count	**No Owls**	6	0	4	0	10
	Single	0	2	4	1	7
	Pair	3	3	7	0	13
	Reproducing Pair	1	0	2	0	3
%	**No Owls**	60%	0%	40%	0%	100%
	Single	0%	29%	57%	14%	100%
	Pair	23%	23%	54%	0%	100%
	Reproducing Pair	33%	0%	67%	0%	100%

<u>1-km CACs</u>: Three variables within the 1-km CACs were significant at $\alpha = 0.10$: *% Unburned* ($p = 0.075$), *% Pine* ($p = 0.003$) and *% Mixed Conifer* ($p = 0.038$) (Table 8, p. 42). Of these three, only *% Pine* was significant after applying the Bonferroni correction. Boxplots help to illustrate why these three variables were significant (Figure 8).

As in the 400-m CACs and the OFS territories, *% Pine* was the clearest and most easily interpretable variable. As before, I found higher percentages of pine in those territories that had no owls. There is a larger amount of variability in those territories with pairs of owls than there was in the 400-m CACs and the OFS territories, but the overall trend is still the same. *% Mixed Conifer* tended to be lowest in those territories with no owls and highest in those territories with reproducing owls, and highly variable in those territories with either single owls or pairs of owls.

Figure 8: Boxplots of *% Unburned, % Pine* and *% Mixed Conifer* predictor variables in 1-km CACs, demonstrating distribution of variable data within each Owl Response level. Horizontal bars within boxes represent the median of the data, the tops and bottoms of the boxes represent the 75th and 25th quantiles of the data, and the whiskers represent the smallest and largest data points lying within 1.5 box lengths. Outlying data are displayed with the symbol "o" and represent data points between 1.5 and 3 box lengths from the box. Extreme outliers are displayed with the symbol "*" and represent data points greater than 3 box lengths from the edge of the box (Norušis 1998).



As with the 400-m CACs, *% Unburned* appears to be significant because of the relatively high percentages of unburned area in those territories that had pairs of owls. There was still high variation within Owl Response levels, however, and the relatively low percentages of unburned area in territories with either single owls or reproducing owls make this a difficult pattern to interpret biologically.

% Pine and *% Mixed Conifer* were highly correlated in the 1-km CACs (Table 16), just as they were in the 400-m CACs. This correlation justifies conducting discriminant analyses on the data. I was able to transform the variables within the OFS territories such that they all met the *Kolmogorov-Smirnov* test for normality, and this set of variables also met the *Box's M* test of equal covariances. Therefore, the assumptions for conducting discriminant analysis were met within the 1-km CACs.

Table 16: Spearman's Rho Correlations - 1-km CACs: The upper right portion of this table represents the Spearman's Rho Correlation Coefficients for each pair of variables, and the lower left portion of the table represents the significance level of that correlation.

	Slope	% North	% East	% South	% West	% Unburned	% Ground Fire	% Canopy Fire	% Stand-Replacement Fire	% Pine	% Pine/Oak	% Mixed Conifer	Topographic Roughness
Average Slope		.102	.108	-.175	.063	-.019	-.009	.110	.064	**-.515****	.325	.200	**.991****
% North	.571		.062	**-.680****	**-.454****	**-.389***	**.517****	.224	.185	.176	.283	-.189	.080
% East	.551	.731		-.224	**-.520****	.150	.098	-.267	-.105	-.305	.004	.058	.075
% South	.329	**.000****	.211		-.083	.159	**-.442****	-.093	-.031	-.071	-.184	.036	-.126
% West	.726	**.008****	**.002****	.647		.141	-.196	.027	-.073	.141	-.159	.079	.058
% Unburned	.915	**.025***	.404	.377	.435		**-.413***	**-.838****	**-.828****	-.233	.001	.125	-.009
% Ground Fire	.959	**.002****	.589	**.010****	.275	**.017***		.273	.073	.127	**.397***	-.169	-.020
% Canopy Fire	.542	.209	.133	.608	.879	**.000****	.124		**.677****	.128	-.083	.175	.087
% Stand-Replacement Fire	.723	.303	.562	.862	.685	**.000****	.688	**.000****		.178	-.108	-.048	.067
% Pine	**.002****	.326	.085	.694	.433	.191	.482	.476	.322		-.103	**-.643****	**-.547****
% Pine/Oak	.065	.110	.984	.304	.377	.997	**.022***	.648	.549	.568		**-.369***	**.350***
% Mixed Conifer	.265	.293	.750	.841	.661	.488	.347	.329	.792	**.000****	**.034***		.210
Topographic Roughness	**.000****	.657	.679	.484	.746	.962	.912	.628	.712	**.001****	**.046***	.241	

Correlation

*Significance Level (2-tailed)****

* *Correlation is significant at the 0.05 level (2-tailed).*

** *Correlation is significant at the 0.01 level (2-tailed).*

*** *Due to the high number of correlations represented here, some correlations may be significant only because of random chance.*

My classification model used the variables *% Pine* and *% Unburned* (Tables 10 and 17). MRPP also identified both of these variables as significant, but, unlike MRPP, the discriminant analysis procedures did not find that *% Mixed Conifer* added enough to include it into the model. The final Wilks' Lambda value for the model (Wilks' Lambda = 0.455) indicates that 45.5% of the variation between Owl Response levels was not accounted for in this model.

The cross-validated classification success rate of this model (51.5%; Table 18) was better than random chance, but far from perfect. As in both the 400-m CACs and the OFS territories, this model never correctly classified a reproducing territory. The model also did relatively poorly at classifying territories with no owls (40% success rate), but it did relatively well at classifying territories with either single owls or with pairs of owls (71% and 62% respectively).

Table 17: Classification Function Coefficients for 1-km CACs

Model Variable	Owl Response Level			
	No Owls	Single Owl	Pair	Reproduction
% Pine	16.031	5.279	12.035	6.327
% Unburned	8.486	4.409	9.582	4.074
(Constant)	-7.441	-2.547	-5.830	-3.503

Table 18: 1-km CACs - Cross Validations and Predictive Accuracy of Discriminant Analysis Model, where each territory is classified by classification functions derived from all territories other than that territory

	Response Level	No Owls	Single	Pair	Reproducing Pair	Total
Count	No Owls	4	0	6	0	10
	Single	0	5	2	0	7
	Pair	4	1	8	0	13
	Reproducing Pair	0	2	1	0	3
%	No Owls	40%	0%	60%	0%	100%
	Single	0%	71%	29%	0%	100%
	Pair	31%	8%	62%	0%	100%
	Reproducing Pair	0%	67%	33%	0%	100%

Influence of Slope, Aspect and Cover Type on Fire Severity

I failed to find patterns between fire severity and topographic/vegetative characteristics.

The three CART models that I developed had an overall average predictive accuracy of approximately 33%, only slightly above random chance. Even worse, the classification criteria developed by the model often went against logic and common sense. Consider the example in Table 19:

Table 19: Typical prediction criteria developed by CART illustrating inconsistency in classification. Data are selected from CART summaries for the OFS territories (See Appendix C for complete CART classification summaries).

Classification Criteria	Predicted Fire Severity
Mixed Conifer; Slope < 3°	Stand Replacement Fire
Mixed Conifer; Slope 3° - 7°; North or East-facing Aspect	Unburned
Mixed Conifer; Slope 20° - 23°; South or West-facing Aspect	Stand Replacement Fire
Mixed Conifer; Slope 19° - 23°; North or East-facing Aspect	Stand Replacement Fire
Mixed Conifer; Slope 23° - 39°	Unburned

Near-random results such as these are not worth discussing in depth, other than to mention that none of the predictor variables (*Slope, Aspect* and *Cover Type*) showed any clear pattern with respect to Fire Severity. Complete CART classification criteria for all three classification models may be found in Appendix C (p. 129).

DISCUSSION

Comparison of Burned and Unburned Territories

There were 6 cases in which burned territories had a higher Owl Response level than their unburned counterparts, 9 ties, and 14 cases in which the unburned territories had a higher Owl Response (Sign test; $p = 0.115$). The presence of fire in a territory, by itself, did not play a significant role in whether a Mexican spotted owl would be present or reproductive in that territory.

The sign test had low power due to my small sample size and the 9 ties. The sign test disregards ties, so the test compared 6 cases where burned territories ranked higher against 14 cases where unburned territories ranked higher. This 30:70 ratio was not significant when $n = 20$ but it would have been significant at $n = 30$ non-tied territory pairs. Anecdotally, all 3 of the

burned sites where I found successful nests occurred in territories where ≥ 50% of the territory had burned (Bridge, p. 83, Riggs Lake, p. 102, and Webb Peak, p. 108), and the most severely burned territory (Circle Cross, p. 86) still had a single owl on it.

Variables associated with Owl Response within the 33 burned territories

My second research objective was to look for significant association between Owl Response and the four fire severity variables measured for each burned territory (*% Unburned, % Surface Fire, % Canopy Fire* and *% Stand Replacement Fire*). My third research objective was to look for significant association between Owl Response and the nine habitat and topographic variables measured for each burned territory (*Average Slope, % North Aspect, % East Aspect, % South Aspect, % West Aspect, % Pine, % Pine/Oak, % Mixed Conifer* and *Index of Topographic Roughness*). I addressed research objectives 2 and 3 simultaneously, first with the nonparametric Multiple Response Permutation Procedure and then with the parametric SPSS Stepwise Discriminant Analysis function. I addressed these questions three separate times, within the 400-m CACs, the 1-km CACs and the Original Forest Service (OFS) territories.

I violated the assumption of normality when analyzing the 400-m CACs because three of the variables were not normally distributed. However, none of these three variables were selected for the final model. According to the Box's M test, I also violated the assumption of equal covariance matrices when analyzing the OFS territories, and results from this analysis should be viewed with this violation in mind.

The stepwise classification models that I developed are most useful in illustrating which variables are correlated with Owl Response. The classification success of the models were too low to comfortably rely on them for actual classification purposes but they were useful for exploring the relationship between those significant variables and Owl Response.

% Pine: MRPP found that *% Pine* was consistently the variable most highly correlated with Owl Response. Furthermore, *% Pine* was the only variable significantly correlated with

Owl Response after applying a Bonferroni correction to the α-level.

In all three territory delineations the discriminant coefficients for *% Pine* were highest in the *No Owls* Owl Response level, and the *% Pine* coefficient was the largest coefficient in the *No Owls* discriminant function, indicating that the *No Owls* Response level was most influenced by the percentage of pine in a territory (Tables 11, 14 and 17). Furthermore, higher percentages of pine lead to higher probabilities that owls will be absent from the territory.

For all three territory delineations and using both MRPP and discriminant function analysis, the percentage of pure pine on a territory was more important in terms of Owl Response than how much, or how severely, that territory was burned. Pine may simply be a relatively poor quality owl habitat where we would expect lower occupancy.

This conclusion is supported by Ganey and Dick (1995) in a review of Mexican spotted owl inventory and monitoring data collected between 1990 and 1993. Out of 346 nest sites and 1,238 roost sites located within five recovery units in the United States portion of the owls' range, only 0% - 2.4% of roost sites and 0% - 1.6% of nest sites were in pine. Roost and nest sites were primarily found in mixed conifer and occasionally in pine/oak, indicating that these cover types may be of considerably higher value to the owl.

<u>% Unburned</u>: Classification models for the 400-m CACs and the 1-km Radius CACs each include the variable *% Unburned* (Tables 11 and 17) In both cases, both the coefficients and the boxplots (Figures 4 and 8) suggest that territories with high rates of unburned area would most likely be classified at either the *Pair* or the *No Owls* response level.

The trend in *% Unburned* was inconsistent and did not make biological sense. There is no clear evidence here to conclude whether *% Unburned* in general is a benefit or a detriment to the owl.

<u>% Stand Replacing Fire</u>: As a matter of speculation, there may be some slight evidence here that higher amounts of stand replacing fire in a territory lead to lower Owl Response levels

in the Forest Service-delineated territories. Classification coefficients for the two lowest Owl Response levels were higher than coefficients for the two highest Owl Response levels, indicating that amounts of stand replacing fire was somewhat more important in territories with either no owls or single owls. The MRPP test showed slight significance, and the boxplots showed relatively low amounts of stand replacing fire in those territories with pairs of owls compared to those territories with either no owls or single owls.

The boxplot for *% Stand Replacing Fire* in OFS territories showed that territories with confirmed reproduction went against this trend, with relatively higher percentages of stand replacing fire in reproductive territories than in territories with pairs of owls. However, there were only three burned territories that had confirmed reproduction, and if we disregard these territories with confirmed reproduction we see a very slight pattern of association between low amounts of *% Stand Replacing Fire* and higher Owl Response levels.

Stepwise discriminant analysis for the 1-km CACs and 400-m CACs did not select *% Stand Replacing Fire* as a classification model variable, nor did MRPP select it as a significant variable in these territory delineations.

<u>Average Slope</u>: MRPP found *Average Slope* was significantly associated with Owl Response in the OFS territories at $\alpha = 0.10$ but not at the Bonferroni-adjusted $\alpha = 0.00769$. As with *% Unburned*, the trend for *Average Slope* was statistically significant but made little biological sense. It is difficult to imagine why territories with single owls should have relatively steep average slopes while territories with either no owls or reproducing owls should have relatively gentle average slopes. There is no clear evidence here to suggest that *Average Slope* in general is either beneficial or detrimental to the owl.

<u>Topographic Roughness</u>: MRPP found *Topographic Roughness* was significantly associated with Owl Response in the OFS territories at $\alpha = 0.10$ but not at the Bonferroni-adjusted $\alpha = 0.00769$. Boxplots of *Topographic Roughness* indicate that territories with either

no owls or reproducing owls tended to have relatively low values for *Topographic Roughness* while territories with single owls have relatively high values. Territories with pairs of owls had highly variable *Topographic Roughness* values (Figure 7).

Topographic Roughness was not selected in any of the classification models. *Topographic Roughness* was highly correlated with *Average Slope* (Table 13) and substituting *Topographic Roughness* for *Average Slope* in that classification model produced very little change in the model's predictive accuracy.

As with *Average Slope*, the trend for *Topographic Roughness* was statistically significant but made little biological sense. There is no clear evidence here to suggest that *Topographic Roughness* in general is either beneficial or detrimental to the owl.

<u>% East-Facing Slope</u>: The classification model for the 400-m CACs included *% East-Facing Slope* as a significant variable (Table 11), but MRPP did not find it significant and the boxplot of *% East-Facing Slope* gave no indication of why this variable would be important. The discriminant coefficient was highest in the *No Owls* Response level, indicating that higher percentages of east-facing slopes may reflect higher chances of not finding owls. I suspect this variable was selected for the 400-m CACs due to a statistical anomaly resulting from low sample sizes; i.e. only 14-16 survey points in each 400-m CAC.

<u>% Mixed Conifer</u>: MRPP found *% Mixed Conifer* was significantly associated with Owl Response in all three territory delineations at $\alpha = 0.10$ but not at the Bonferroni-adjusted $\alpha = 0.00769$. Higher percentages of mixed conifer were strongly associated with reproductive owls. The trend here is clear and makes biological sense. Mexican spotted owls nest and roost most commonly in mixed conifer forests (Ganey and Dick 1995) and it stands to reason that higher percentages of mixed conifer forest in a territory would reflect higher quality habitat for the owl.

Stepwise discriminant analysis never included *% Mixed Conifer* into any of the

classification models. *% Mixed Conifer* was highly correlated with *% Pine* (Tables 9, 13 and 16) and once *% Pine* was included in the models, *% Mixed Conifer* never added enough discrimination ability to the models to justify including it.

% North-Facing Slope: MRPP found *% North-Facing Slope* was significantly associated with Owl Response in the OFS territories at $\alpha = 0.10$ but not at the Bonferroni-adjusted $\alpha = 0.00769$. Boxplots of *% North-Facing Slope* indicate that the reason for significance appears to be the relatively low percentages of north-facing slope occurring within the reproductive territories (Figure 6). I suspect the significance of *% North-Facing Slope* is due to the very small number of cases of reproducing territories ($n = 3$), and that these three reproducing territories coincidentally had relatively low percentages of north-facing slopes within the OFS territory boundaries. *% North-Facing Slope* was not significant within the 400-m CACs or the 1-km CACs, or in the stepwise discriminant analysis classification models.

Variables associated with Severity of Burn within the 33 burned territories

The three variables that I measured, namely *Slope, Aspect* and *Cover Type* were not sufficient to describe fire behavior. Fire behavior is mainly influenced by humidity, wind speed, wind direction, fuel moisture, fuel composition, fuel buildup and the presence of fuel ladders (Pyne et al. 1996; DeBano et al. 1998), and describing fire behavior without considering these other variables is an exercise in futility. Even if I had data on the climate and fuel variables for each fire, it would be difficult to relate them to particular survey points because wind and weather change constantly through the course of a day.

Furthermore, my survey points were not independent. In other words, the probability of a survey point being burned at a particular level was not equal for all points. Fire severity at any one point was heavily influenced by the fire severity of adjacent points, and this lack of independence badly compromised the statistical soundness of the CART analysis. Some method must be found to take the spatial dependence of the survey points into account.

Comparison of three territory delineations

I was interested in seeing if results from simple circular designs yielded results similar to the habitat-based OFS territories. If so, future research efforts could justify using a simpler, less subjective circular sampling design.

I usually found similar results with all three territory delineations. MRPP and stepwise discriminant analysis consistently identified *% Pine* as most associated with Owl Response in all three delineations.

However, in each territory delineation, one or more variables were either significantly associated with Owl Response or they added significantly to the discriminant model, but in ways that were not biologically reasonable. These apparently spurious findings involved 2 variables in the 400-m CACs (*% East-Facing Slope* and *% Unburned*), 2 variables in the OFS territories (*Average Slope* and *Topographic Roughness*), and 1 variable in the 1-km CACs (*% Unburned*).

I suspect the 400-m CACs were most prone to such anomalies due to the low number of survey points within each circle. This small sampling design may be unacceptably sensitive to small differences in habitat characteristics within a relatively small portion of the owls' home range, but this could perhaps be remedied by increasing the number of sampling points at least two fold.

Analyses in the OFS territories and the 1-km CACs yielded generally similar results and neither yielded "more accurate" results. Because the 1-km CACs have a constant size and shape and are, therefore, more amenable to statistical analysis, they may be preferable in research settings when Forest Service delineations are missing, or vary in size, among territories to be studied.

Suggestions for Future Research

This thesis addressed the effects of fire on Mexican spotted owls, and compared owl presence and reproduction in territories with different severities of fire and a variety of different

habitat and topographic characteristics. I found little or no evidence that the presence or severity of fire played a significant role in owl response. However, because I lacked appropriate data or because my sample of burned territories was too small, I was unable to address how the following 4 factors influenced owl response to fire.

<u>Length of time since the fire</u>: All the territories I examined had been burned within the four years prior to my field season. I suspect that the short term effects of fire on these owls are probably greater than the long term effects, although my data do not show this. The most dramatic change in owl habitat, and, therefore, Owl Response, should occur the year of the fire, but the longer term (2-5 year) responses are biologically more important to a regional population and should be the main focus of research.

<u>Season of fire</u>: Fire behaves differently in different seasons, and the ecosystem reacts differently to fires that burn inside or outside of the natural fire season. The fire season in southwestern forests occurs primarily in the mid-to-late summer, when monsoons bring a lot of lightning, and to a lesser extent in late spring. Most prescribed fires are conducted outside this natural fire season because there is less chance of the fire getting out of control, but plants and animals may be more susceptible to fire in early spring or late fall. For example, ground fires burning into the duff can send lethal temperatures much deeper into damp soil than it can into dry soil, so prescribed fires conducted in early spring may cause significantly more mortality of small plants and animals than prescribed fires in the fall. Therefore, the season of the fire could have direct and indirect effects on the prey base of the owl.

<u>Fire proximity to nesting and roosting stands</u>: It seems reasonable that fires burning in a nest stand could have a greater impact on an owl than fires burning in a marginal foraging stand. Unfortunately I did not have nest locations for many spotted owl territories in this study.

<u>Repeated fires vs. Single events</u>: Most of the territories I looked at had been burned only one time in the four years prior to my field season, but three (Tadpole #1, #2 and #3; Appendix

B, p. 92) had been burned multiple times. There were not enough cases of multiple burns for me to conduct a statistical analysis on them, but anecdotally two of these three territories had single birds on them and the third territory had a pair.

Management Implications

Data from this study show no evidence of owl presence or reproduction being significantly affected by recent fire in a territory. Furthermore, of the 13 habitat and fire severity variables that I measured for each of the burned territories, none of the fire severity variables showed a clear influence on owl response. Therefore, I feel that fire in a territory, especially light fire that does not cause widespread stand replacement, should not have a short-term negative or positive impact on the Mexican spotted owl.

None of the territories that I examined had greater than 55% stand replacement burn within the OFS territory boundary so I cannot draw conclusions regarding fires that burn more severely than that. Owls probably would not occupy a territory that had a 100% stand replacement burn, thus the threshold level of fire extent apparently lies somewhere between 55% and 100%.

I suspect that the only real fire-related threat to the owl would be from wide-scale, stand replacing fire that dramatically reduces structural diversity and roosting and nesting habitat. Such fires are becoming more common in the southwest, and prescribed fire is a powerful tool for dealing with this threat. Since prescribed fire rarely reaches wide-scale stand replacing intensity, it should have no direct effect on the owl while reducing the threat of potentially damaging fires. Prescribed fire in up to 50% of a territory should, therefore, be a useful tool within Mexican spotted owl territories.

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APPENDIX A: Field Data Forms

1997 Mexican Spotted Owl Fire Study Inventory Form 75

1997 Mexican Spotted Owl Fire Study *Daytime Follow-up Visit* Form 76

1997 Mexican Spotted Owl Fire Study *Day Roost/Nest Site* Data Form 78

1997 Mexican Spotted Owl Cover Type and Fire Severity Inventory Form 79

Grid Overlay for establishing Fire Severity and Cover Type Survey Points 80

1997 Mexican Spotted Owl Fire Study Inventory Form

Inventory Area________________________ PAC Number________________ Date______________

Forest______________ District______________ Quad Map Name(s)______________________________

Survey Type: Nighttime___ Daytime___ Survey #_______ Complete Survey?____

Outing #_____ Aborted?_____ Results____________________ % Area Surveyed__________

Observers ____________________ ____________________ ____________________

Call Point	Survey Method	Time			Call Meth	Moon Vis?	Raptor Response											
												Bearing		Weather *Fill out for all calling locations*			UTM	
		Start	End	Total			A/V	Sex	Age	Spp	Time	1st	2nd	Wind	Cloud	PPT	E	N

- **Date:** should be in MM/DD/YY format.
- **Outing #:** For cases where it takes multiple outings to complete the survey.
- **Call Point:** Label point on map and reference it here.
- **Survey Method:** **CP** = Call Point
  CC = Continuous Calling Route
  LF = Leap Frog Method
- **Start/Stop:** Should be in military time (0900 - 1300)
- **Call Method:** **V** = Vocal or **R** = Recorded calls: Should primarily be Vocal.
- **Raptor Response A/V:** **A** = Audio or **V** = Visual location
- **Sex: M, F, U**
- **Age:** **J** = Juvenile
  S = Sub-Adult (Requires visual observation
  A = Adult
- **Spp:** Species (4-letter abbreviation: SPOW, GHOW)
- **Wind:** **0** = < 1 mph: Smoke rises straight up
  1 = 1-3 mph: Smoke drifts
  2 = 4-7 mph: Wind felt on face, leaves rustle
  3 = 8-12 mph: Leaves/small twigs in constant motion
  4 = 13-18 mph: Raises dust, moves small branches
  5 = 19-24 mph: Small trees in leaf sway
  6 = >24 mph: Large trees in leaf sway.
  - **DO NOT CALL IF WIND > 3!!!**
- **Cloud:** **0-100%**, estimate to nearest 10% cloud cover
- **PPT:** Precipitation: **0** = None
  1 = fog
  2 = light rain
  3 = heavy rain

4 = light snow
5 = heavy snow

UTM: E = Easting; should be 6 digits.
N = Northing; Should be 7 digits.
- Estimate to nearest 10 meters!

Don't forget to attach map with calling locations and any raptor locations labeled!

1997 Mexican Spotted Owl Fire Study *Daytime Follow-up Visit* Form

Forest______________________ District__________________ Date__________

Inventory Area__________________________ PAC#______________________

Quad Map Names____ Visit #_____

Observers____

Follow-up Visit for Inventory #__________ Date Presence Detected______________

Date Single Inferred_______________ Date Pair Confirmed______________

UTM Location: Northing______________ Easting_____________ Zone__________

Weather: Wind_____ Clouds_____ PPT_____

Survey Time: Begin______ End______ Total______

Owl Response: (Circle One) *Visual* *Vocal* *None*

Owls Present: Adult/Subadult_____________ *(#, F = Female, M = Male, S = Subadult, U = Unknown)*

Nestlings______________ # Young______________

Dead Owls (Identify)____________________________

Reproductive Status: (Circle One) *Not Nesting* *Active, On Nest* *Active, Not On Nest* *Unknown*

Mousing used?______ Number Used_____

Fate of Mouse taken by:

Male	Female	Unknown Sex	
Mouse 1:_____	Mouse 1:_____	Mouse 1:_____	Mouse 5:_____
Mouse 2:_____	Mouse 2:_____	Mouse 2:_____	Mouse 6:_____
Mouse 3:_____	Mouse 3:_____	Mouse 3:_____	Mouse 7:_____
Mouse 4:_____	Mouse 4:_____	Mouse 4:_____	Mouse 8:_____

***I** = Ignores* ***C** = Cached* ***F** = Took to Female* ***Y** = Took to Young* ***N** = Took to Nest* ***A** = Ate*
***L** = Left with Mouse, Fate unknown* ***G** = Mouse got away* ***H** = Holds for 1 hour*

Nest Located?_________ Evidence Used:______________________________________

____

Day Roost Located?___________

Other Raptors Heard/Seen____

____

Comments____

____

____

____

____

____

- Continue Comments on Back of Page -

1997 Mexican Spotted Owl Fire Study *Day Roost/Nest Site* Data Form

Forest_______________________ District_______________________ Date_____________

Inventory Area_______________________________ PAC#______________________________

Quad Map Names____

Observers____

Location type: (Circle one) ***Roost*** ***Nest***

UTM Location: Northing________________ Easting_________________ Zone_____________

Single Tree?_________ Grove?_______ *(Describe Grove in Comments)*

Topography (Circle One):

Level *Steep (No Rock)* *Steep (Rock)* *Ridge-Top* *Drainage Bottom* *Rock Wall*

Slope Position (Circle One): *Upper ⅓* *Middle ⅓* *Lower ⅓*

Forest Type (Circle One):

Ponderosa Pine *Pine/Oak* *Mixed Conifer* *Spruce/Fir* *Cottonwood/Riparian* *Other Riparian*

Pinyon/Juniper *Other*___________________________

Substrate (Circle One):

Branch *Witches-Broom* *Platform* *Tree-Cavity* *Cliff* *Cave* *Other nest*

Tree or Cliff Data (*Fill in what is appropriate*):

Diameter_________ Species____________ Tree/Cliff Height________ Roost Height_______

Comments: (Include description on how to find nest or roost site)________________________

____

____

____

____

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____

____

____

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____

____

1997 Mexican Spotted Owl Cover Type and Fire Severity Inventory Form

Territory Name________________________ **Forest**________________________

Name________________________ **Date**________________________

Point number_____ **UTM Coordinates:** E______________ N______________

Within 10m radius circle:

Dominant pre-fire overstory tree species[1] ______________ Dominant pre-fire understory tree species[1]______________

Evidence of recent ground fire (within last 5 years)?[2]_______ Evidence of recent crown fire (within last 5 years)?[3]_______

Complete stand replacement burn?[4]______

Point number_____ **UTM Coordinates:** E______________ N______________

Within 10m radius circle:

Dominant pre-fire overstory tree species[1] ______________ Dominant pre-fire understory tree species[1]______________

Evidence of recent ground fire (within last 5 years)?[2]_______ Evidence of recent crown fire (within last 5 years)?[3]_______

Complete stand replacement burn?[4]______

Point number_____ **UTM Coordinates:** E______________ N______________

Within 10m radius circle:

Dominant pre-fire overstory tree species[1] ______________ Dominant pre-fire understory tree species[1]______________

Evidence of recent ground fire (within last 5 years)?[2]_______ Evidence of recent crown fire (within last 5 years)?[3]_______

Complete stand replacement burn?[4]______

Point number_____ **UTM Coordinates:** E______________ N______________

Within 10m radius circle:

Dominant pre-fire overstory tree species[1] ______________ Dominant pre-fire understory tree species[1]______________

Evidence of recent ground fire (within last 5 years)?[2]_______ Evidence of recent crown fire (within last 5 years)?[3]_______

Complete stand replacement burn?[4]______

Point number_____ **UTM Coordinates:** E______________ N______________

Within 10m radius circle:

Dominant pre-fire overstory tree species[1] ______________ Dominant pre-fire understory tree species[1]______________

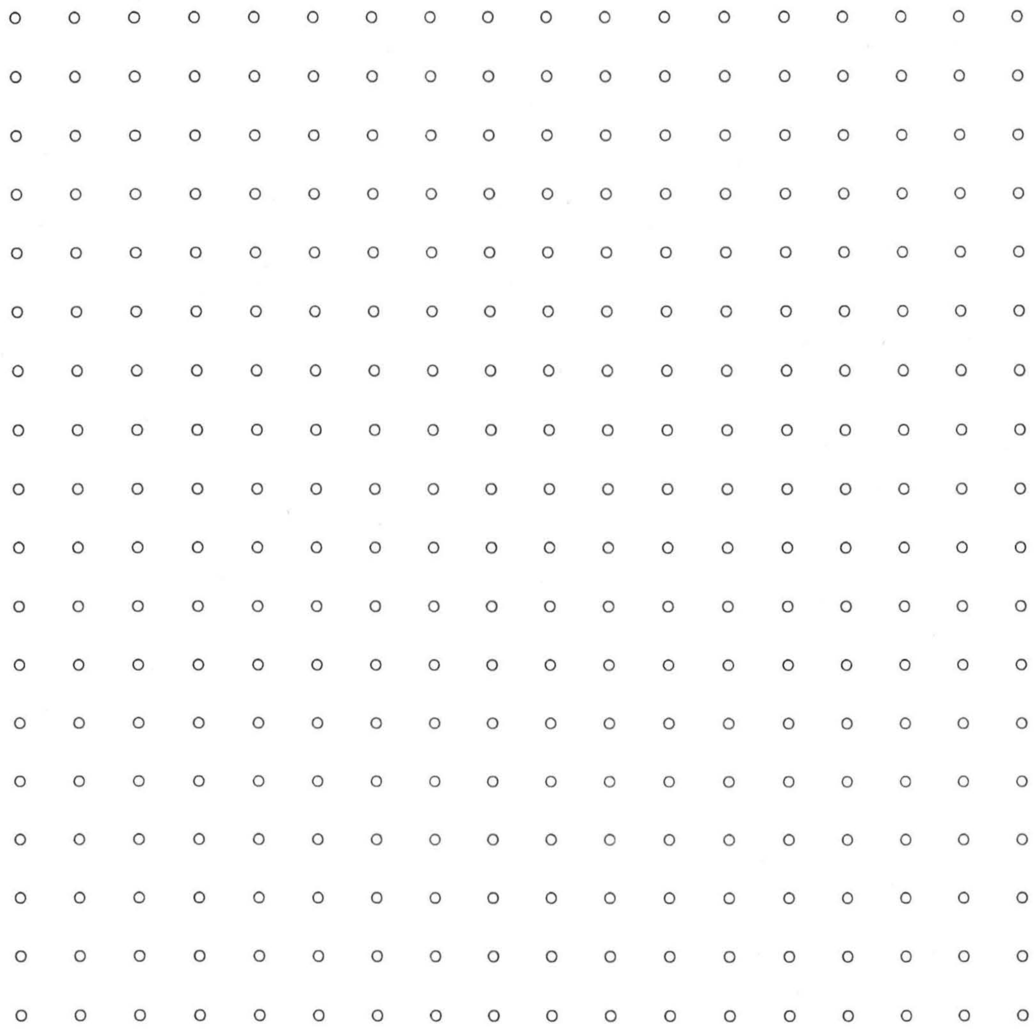
Evidence of recent ground fire (within last 5 years)?[2]_______ Evidence of recent crown fire (within last 5 years)?[3]_______

Complete stand replacement burn?[4]______

---

[1] ***Pine, Pine-Oak, Mixed Conifer, Aspen, P-J, Riparian, etc.*** or ***Opening*** (non-fire related opening, such as meadow, cliff-face, stream-bottom, etc.) If *Opening*, explain what kind of opening it is.
[2] Look for scorching along bases of trees, and bare patches on ground where soil was baked.
[3] Especially snags with scorch marks on branches and trunk.
[4] All canopy within 10m of point burned.

Grid Overlay for establishing Fire Severity and Cover Type Survey Points



Approximately one dot per 3.4 hectares or 8.5 acres

Distance between dots ≈ 186 meters or 610 feet.

APPENDIX B: Individual Territory Summaries and Maps

Lincoln Territories

Bridge territory (MT #0802014) 83
Carr territory (MT #0802018) 84
Fire territory (MT #0802073) 85
Circle Cross territory (MT #0802089) 86
Scott Able territory (MT #0802061) 87

Gila Territories

Gila Woods territory (MT #0606030) 89
Juniper Saddle territory (MT #0606043) 89
Piney Park territory (MT #0606069) 90
Wilson territory (MT #0606042) 90
Tadpole #1 territory (MT #0607005) 92
Tadpole #2 territory (MT #0607006) 93
Tadpole #3 territory (MT #0607007) 93

Coronado Territories

Hunter Canyon territory (MT #0503017) 95
Miller Canyon territory (MT #0503001) 96
Loma Linda territory (MT #0505008) 97
Red Ridge territory (MT #0505014) 98
Mill Site territory (MT #0504007) 99
Mormon Canyon territory (MT #0501008) 100
Rattlesnake Peak territory (MT #0501013) 101
Riggs Lake territory (MT #0504003) 102
Romero Canyon territory (MT #0505018) 104
Shovel Springs territory (MT #0505013) 105
Rucker Canyon territory (MT #0501009) 106
Upper Cunningham territory (MT #0504013) 107
Webb Peak territory (MT #0504006) 108

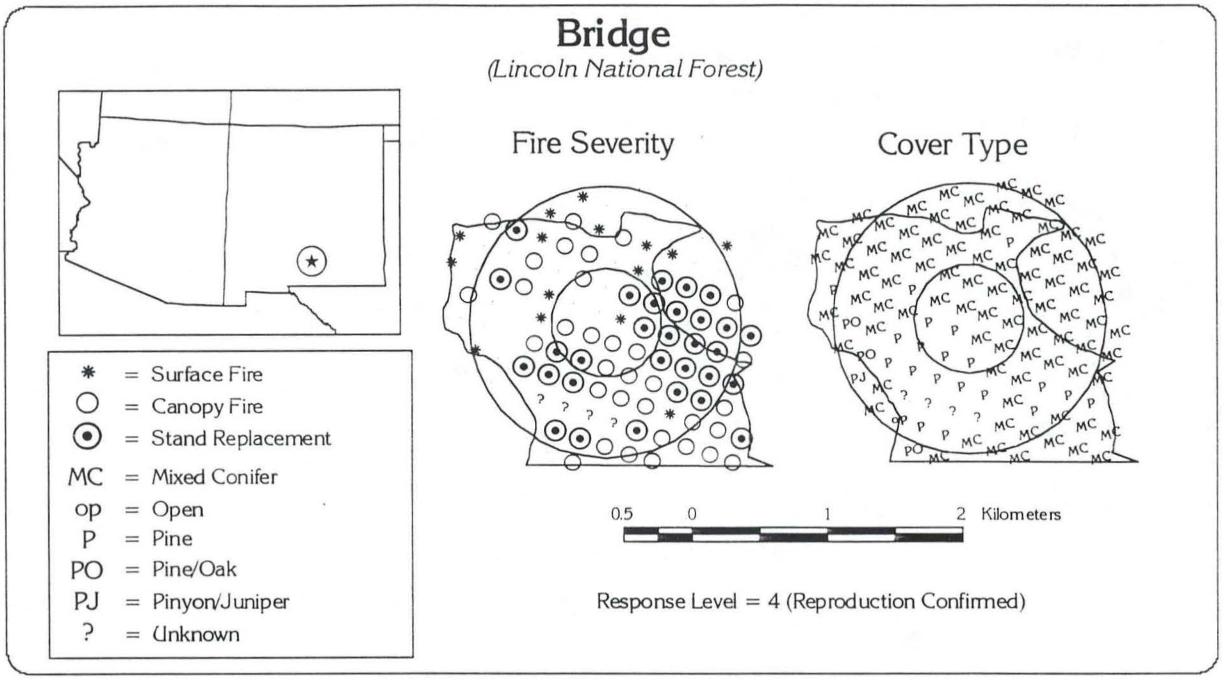
Coconino Territories

East Bear Jaw territory (MT #040233) 109
Hochderffer territory (MT #040232) 110
Orion Springs territory (MT #040207) 111
Red Hill territory (MT #040224) 112
Secret Cabin territory (MT #040222) 113
Secret Canyon territory (MT #040605) 114
Secret Mountain territory (MT #040604) 115
Upper West Fork territory (MT #040212) 116

Case Summaries for Original Territories, 1-km CACs and 400-m CACs

Table B1: Topographic Summaries for OFS Territories (Forest Service Delineated PACs and Cores) 117
Table B2: Fire and Vegetative Summaries for OFS Territories (Forest Service Delineated PACs and Cores) 119
Table B3: Topographic Summaries for 1-km Circular Activity Centers (CACs) . . . 121
Table B4: Fire and Vegetative Summaries for 1-km CACs 123
Table B5: Topographic Summaries for 400-m CACs 125
Table B6: Fire and Vegetative Summaries for 400-m CACs 127

Lincoln Territories

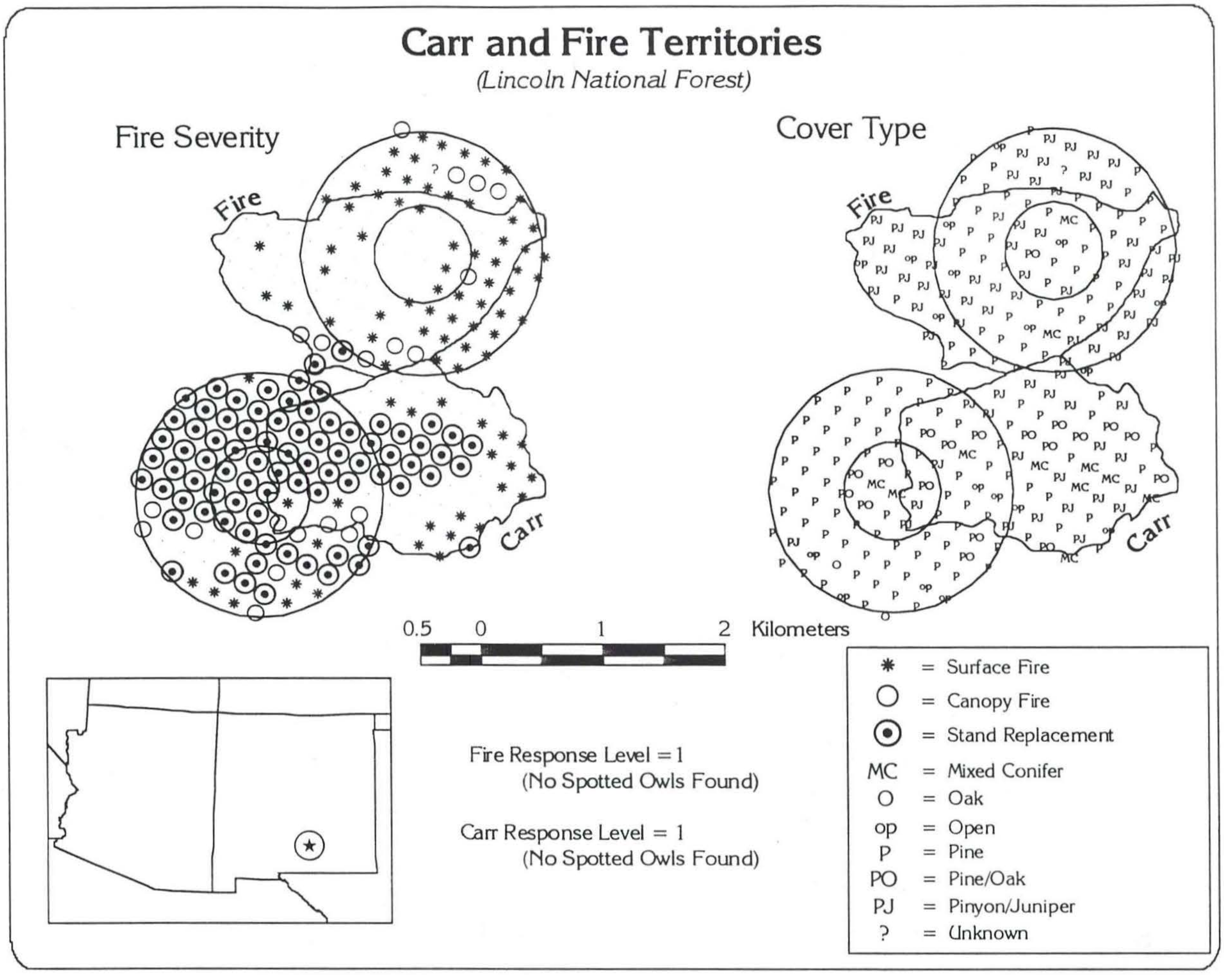


The Bridge territory (MT #0802014) is located on the Lincoln National Forest south of Cloudcroft, NM. The original territory size is 291 hectares (719 acres) and the addition of our 1-km radius circle increased our survey area to 368 ha (908 ac). The original territory ranges in elevation from 2,331 - 2,531 meters (7,648 - 8,304 feet) and lies predominately on south-facing slopes, with 42% of the territory having an aspect between 135°- 225°. The average slope over the territory is 13.3°. The Bridge territory was paired with the unburned Danley territory located approximately 2 kilometers to the north.

Along with the Circle Cross and Scott Able territories, the Bridge territory was burned by the Bridge fire in 1994. We had 83 habitat survey points within this original territory boundary and 22% of these showed no evidence of recent fire. 12% showed only evidence of ground fire, 35% burned to some degree (but not completely) into the canopy and 27% showed complete stand replacement burn. 5% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 24% of the territory had a Pine cover type, 4% had a mixture of Pine and Oak, and 67% had a Mixed Conifer cover type. 5% was unknown.

Spotted Owl Monitoring History for Bridge Territory (adapted from Salas [1996])									
1988	1989	1990	1991	1992	1993	1994	1995	1996	***1997***
Pair	Nest (2 young)	Pair	Pair	Absent	Not Surveyed	Pair	Pair	Single	***Nest (1 young)***



The Carr territory (MT #0802018) is located on the Lincoln National Forest east of Cloudcroft, NM. The original territory size is 255 hectares (630 acres) and the addition of our 1-km radius circle increased our survey area to 483 ha (1,194 ac). The original territory ranges in elevation from 2,051 - 2,280 meters (6,729 - 7,480 feet) and lies predominately on south-facing slopes, with 46% of the territory having an aspect between 135°- 225°. The average slope over the territory is 16.4°. The Bridge territory was paired with the unburned Walker territory located approximately 5 kilometers to the north.

Along with the Fire territory, the Carr territory was burned by the Burgett fire in 1993. We had 73 habitat survey points within this original territory boundary and 29% of these showed no evidence of recent fire. 26% showed only evidence of ground fire, 4% burned to some degree (but not completely) into the canopy and 41% showed complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 38% of the territory had a Pine cover type, 16% had a mixture of Pine and Oak,

and 10% had a Mixed Conifer cover type. 36% was classified as "Other".

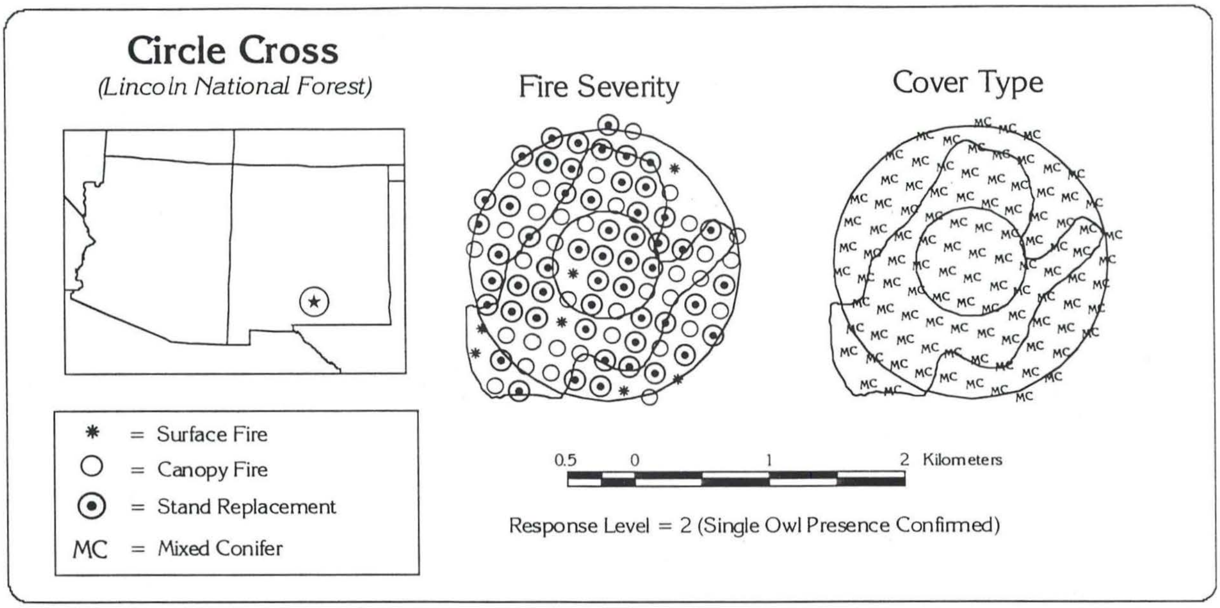
Spotted Owl Monitoring History for Carr Territory (adapted from Salas [1996])									
1988	1989	1990	1991	1992	1993	1994	1995	1996	*1997*
Pair	Pair	Absent	Not Surveyed	Absent	Absent	Absent	Absent	Not Surveyed	***Absent***

The Fire territory (MT #0802073) is located on the Lincoln National Forest east of Cloudcroft, NM. The original territory size is 272 hectares (676 acres) and the addition of our 1-km radius circle increased our survey area to 382 ha (944 ac). The original territory ranges in elevation from 2,051 - 2,251 meters (6,729 - 7,385 feet) and lies predominately on south-facing slopes, with 40% of the territory having an aspect between 135°- 225°. The average slope over the territory is 13.9°. The Fire territory was paired with the unburned Sixteen Springs territory located approximately 2.5 kilometers to the north.

Along with the Carr territory, the Fire territory was burned by the Burgett fire in 1993. We had 78 habitat survey points within this original territory boundary and 49% of these showed no evidence of recent fire. 41% showed only evidence of ground fire, 8% burned to some degree (but not completely) into the canopy and 3% showed complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 49% of the territory had a Pine cover type, 1% had a mixture of Pine and Oak, and 3% had a Mixed Conifer cover type. 47% was classified as "Other".

Spotted Owl Monitoring History for Fire Territory (adapted from Salas [1996])									
1988	1989	1990	1991	1992	1993	1994	1995	1996	*1997*
Single	Absent	Pair	Pair	Pair	Pair	Single	Absent	Not Surveyed	***Absent***



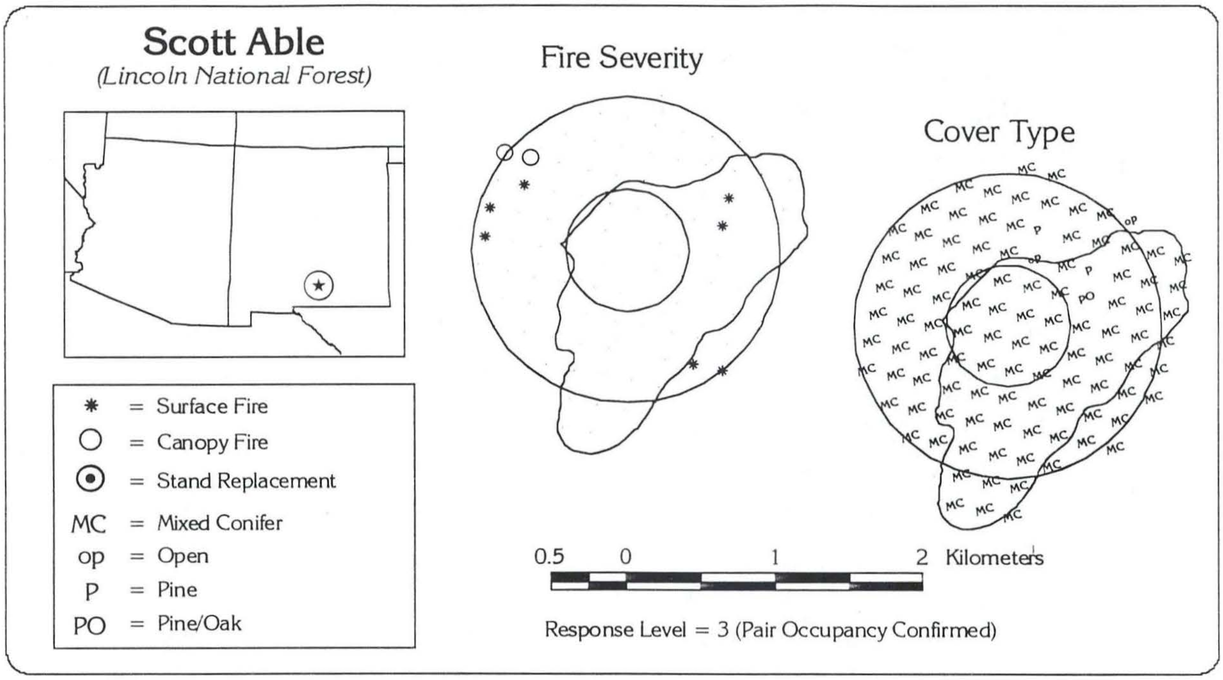
The Circle Cross territory (MT #0802089) is located on the Lincoln National Forest south of Cloudcroft, NM. The original territory size is 195 hectares (481 acres) and the addition of our 1-km radius circle increased our survey area to 331 ha (817 ac). The original territory ranges in elevation from 2,341 - 2,719 meters (7,680 - 8,921 feet) and lies predominately on south-facing slopes, with 49% of the territory having an aspect between 135° - 225°. The average slope over the territory is 16.2°. The Circle Cross territory was paired with the unburned Carrisa territory located approximately 6.5 kilometers to the east.

Along with the Bridge and Scott Able territories, the Circle Cross territory was burned by the Bridge fire in 1994. We had 56 habitat survey points within this original territory boundary and all of them showed some evidence of recent fire. 7% showed only evidence of ground fire, 38% burned to some degree (but not completely) into the canopy and 55% showed complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 100% of the territory had a Mixed Conifer cover type.

Spotted Owl Monitoring History for Circle Cross Territory (adapted from Salas [1996])

1988	1989	1990	1991	1992	1993	1994	1995	1996	*1997*
Single	Nest (1 young)	Absent	Nest (2 young)	Absent	Not Surveyed	Pair	Absent	Single	***Single***



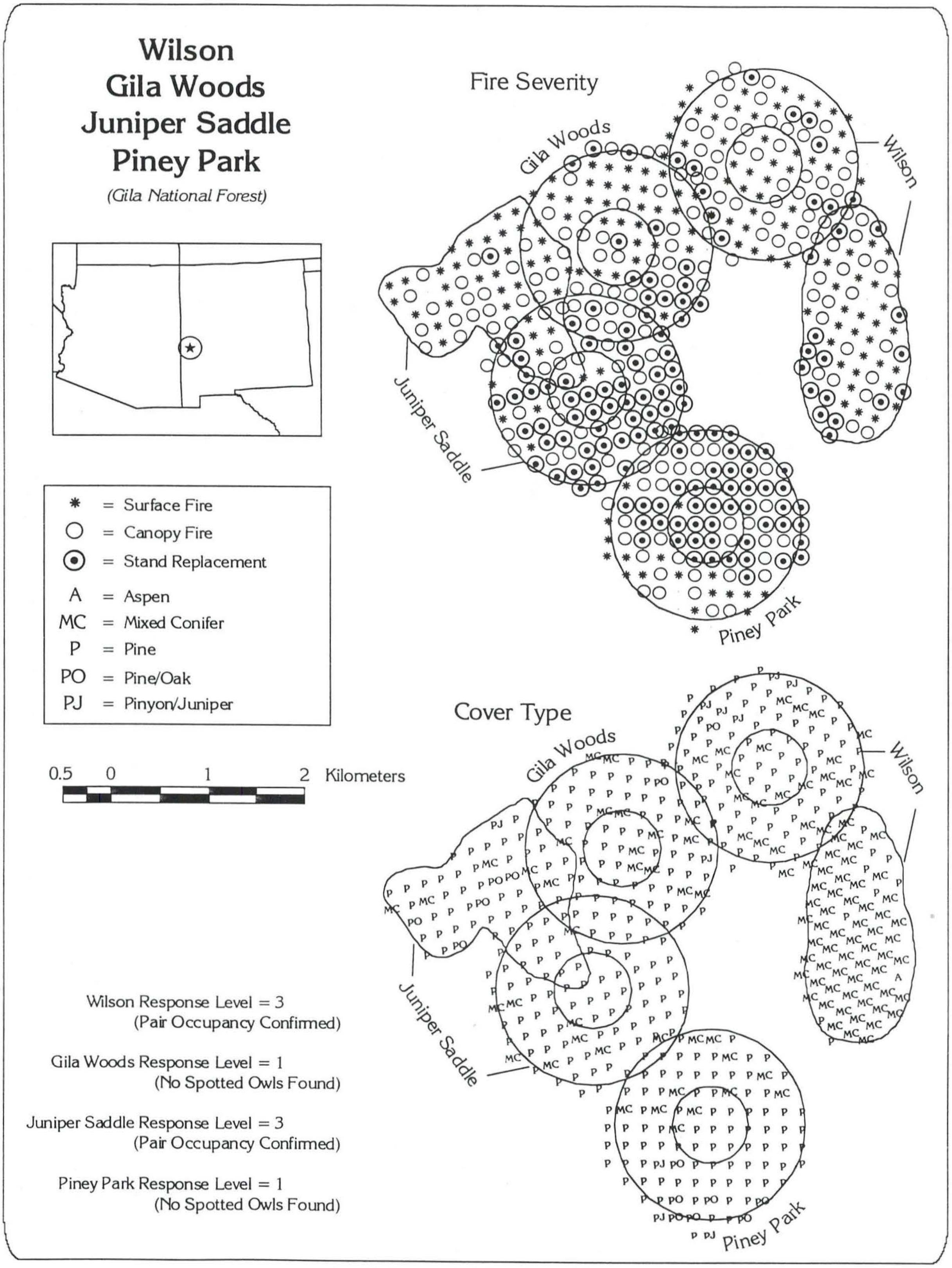
The Scott Able territory (MT #0802061) is located on the Lincoln National Forest south of Cloudcroft, NM. The original territory size is 189 hectares (466 acres) and the addition of our 1-km radius circle increased our survey area to 343 ha (849 ac). The original territory ranges in elevation from 2,359 - 2,658 meters (7,739 - 8,720 feet) and lies predominately on west-facing slopes, with 42% of the territory having an aspect between 45°- 135°. The average slope over the territory is 18.7°. The Scott Able territory was paired with the unburned Jeffers territory located approximately 8 kilometers to the east.

Along with the Circle Cross and Bridge territories, the Scott Able territory was burned by the Bridge fire in 1994. We had 54 habitat survey points within this original territory boundary and 96% of these showed no evidence of recent fire. 4% showed only evidence of ground fire, and no points showed any sign of canopy or complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 2% of the territory had a Pine cover type, 2% had a mixture of Pine and Oak, and 96% had a Mixed Conifer cover type. 0% was unknown.

Spotted Owl Monitoring History for Scott Able Territory (adapted from Salas [1996])									
1988	1989	1990	1991	1992	1993	1994	1995	1996	***1997***
Single	Nest (2 young)	Single	Pair	Nest (1 young)	Not Surveyed	Pair	Absent	Single	***Pair***

Gila Territories



The Gila Woods territory (MT #0606030) is located on the Gila National Forest east of Reserve, NM. I could find no records of an original territory delineation so I used the 1-km radius circle as the complete survey area. This 1-km circle is 313 hectares (772 acres) in size. The territory ranges in elevation from 2,280 - 2,651 meters (7,480 - 8,697 feet) and lies predominately on north-facing slopes, with 48% of the territory having an aspect between 315°- 45°. The average slope over the territory is 17.8°. The Gila Woods territory was paired with the unburned McCarty territory located approximately 7.2 kilometers away.

Along with the Juniper Saddle, Piney Park and Wilson territories, the Gila Woods territory was burned by the HB fire in 1995. We had 89 habitat survey points within this 1-km circle and 2% of these showed no evidence of recent fire. 43% showed only evidence of ground fire, 39% burned to some degree (but not completely) into the canopy and 16% showed complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 82% of the territory had a Pine cover type, 1% had a mixture of Pine and Oak, and 16% had a Mixed Conifer cover type. 1% was classified as "Other".

This territory was surveyed for owls by Chris May and his demography crew, who graciously shared their findings with us. The territory was selected for inclusion in the study based on previous years of locations from May's study (May 1996; Boucher and Pope 1996). May's survey effort in 1997 turned up no spotted owls (May 1997).

The Juniper Saddle territory (MT #0606043) is located on the Gila National Forest east of Reserve, NM. The original territory size is 238 hectares (587 acres) and the addition of our 1-km radius circle increased our survey area to 501 ha (1,238 ac). The original territory ranges in elevation from 2,268 - 2,575 meters (7,441 - 8,448 feet) and lies predominately on north-facing slopes, with 46% of the territory having an aspect between 315°- 45°. The average slope over the territory is 16.9°. The Juniper Saddle territory was paired with the unburned Deep Canyon territory located approximately 7.3 kilometers away.

Along with the Gila Woods, Piney Park and Wilson territories, the Juniper Saddle territory was burned by the HB fire in 1995. We had 69 habitat survey points within this original territory boundary and 1% of these showed no evidence of recent fire. 49% showed only evidence of ground fire, 41% burned to some degree (but not completely) into the canopy and 9% showed complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 84% of the territory had a Pine cover type, 7% had a mixture of Pine and Oak, and 7% had a Mixed Conifer cover type. 1% was classified as "Other".

This territory was surveyed for owls by Chris May and his demography crew, who graciously shared their findings with us. The territory was selected for inclusion in the study based on previous years

of locations from May's study (May 1996; Gutierrez et al. 1996; Boucher and Pope 1996). May's survey effort in 1997 turned up a pair of spotted owls (May 1997).

The Piney Park territory (MT #0606069) is located on the Gila National Forest east of Reserve, NM. I could find no records of an original territory delineation so I used the 1-km radius circle as the complete survey area. This 1-km circle is 313 hectares (772 acres) in size. The territory ranges in elevation from 2,497 - 2,881 meters (8,192 - 9,452 feet) and lies predominately on south-facing slopes, with 45% of the territory having an aspect between 135°- 225°. The average slope over the territory is 18.9°. The Piney Park territory was paired with the unburned Bear Canyon territory located approximately 11.2 kilometers away.

Along with the Juniper Saddle, Gila Woods and Wilson territories, the Piney Park territory was burned by the HB fire in 1995. We had 88 habitat survey points within this 1-km circle and 3% of these showed no evidence of recent fire. 15% showed only evidence of ground fire, 35% burned to some degree (but not completely) into the canopy and 47% showed complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 80% of the territory had a Pine cover type, 7% had a mixture of Pine and Oak, and 13% had a Mixed Conifer cover type. 1% was classified as "Other".

This territory was surveyed for owls by Chris May and his demography crew, who graciously shared their findings with us. The territory was selected for inclusion in the study based on previous years of locations from May's study (May 1996; Boucher and Pope 1996). May's survey effort in 1997 turned up no spotted owls (May 1997).

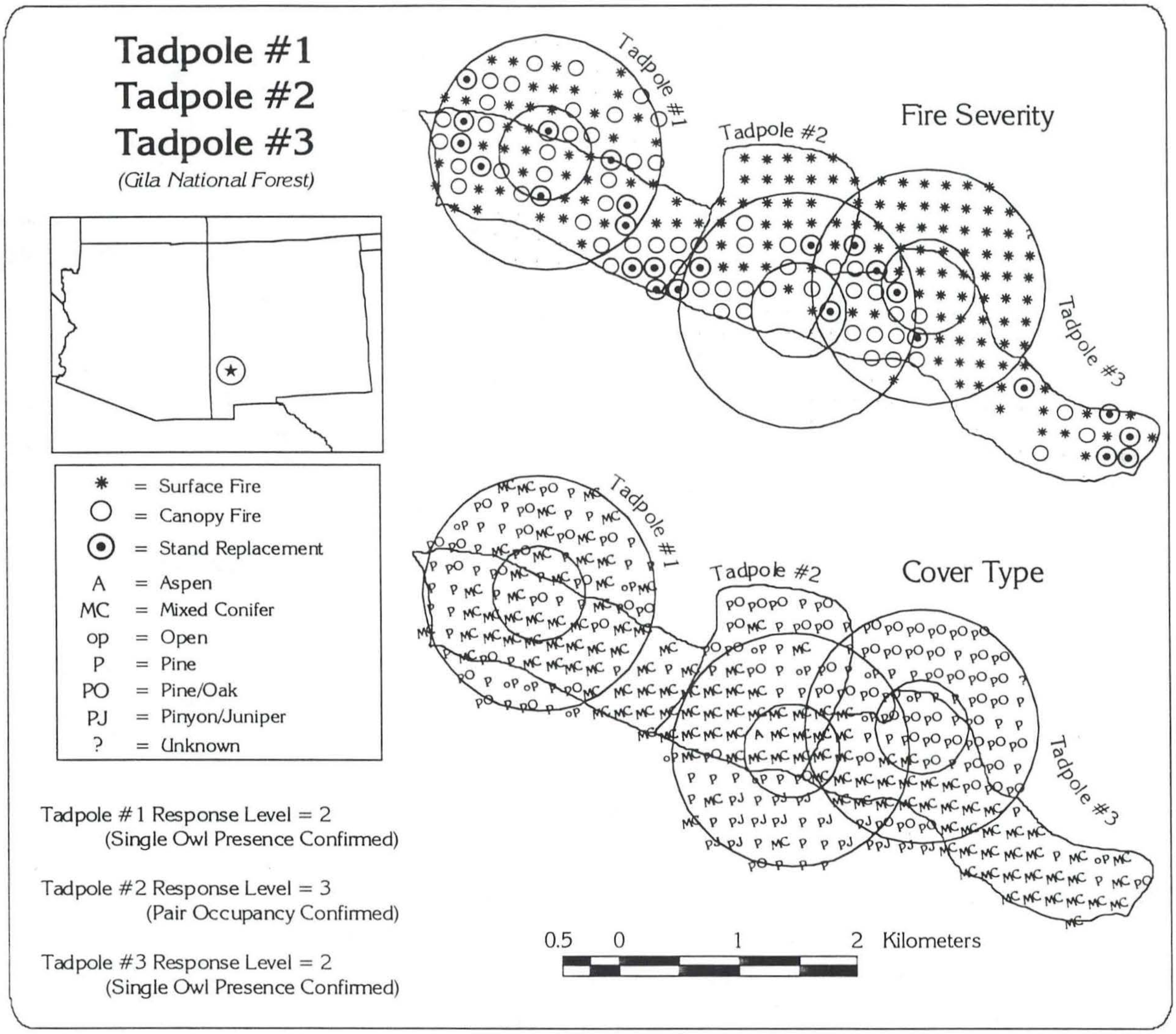
The Wilson territory (MT #0606042) is located on the Gila National Forest east of Reserve, NM. The original territory size is 232 hectares (573 acres) and the addition of our 1-km radius circle increased our survey area to 539 ha (1,332 ac). The original territory ranges in elevation from 2,444 - 2,906 meters (8,018 - 9,534 feet) and lies predominately on east- and west-facing slopes, with 35% of the territory having an aspect between 45°- 135° and 37% of the territory having an aspect between 225°- 315°. The average slope over the territory is 19.5°. The Wilson territory was paired with the unburned White Rocks territory located approximately 6.6 kilometers away.

Along with the Gila Woods, Piney Park and Juniper Saddle territories, the Wilson territory was burned by the HB fire in 1995. We had 69 habitat survey points within this original territory boundary and 1% of these showed no evidence of recent fire. 42% showed only evidence of ground fire, 33% burned to some degree (but not completely) into the canopy and 23% showed complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 14% of the territory had a Pine cover type, 0% had a mixture of Pine and Oak,

and 84% had a Mixed Conifer cover type. 1% was classified as "Other".

This territory was surveyed for owls by Chris May and his demography crew, who graciously shared their findings with us. The territory was selected for inclusion in the study based on previous years of locations from May's study (May 1996; Gutierrez et al. 1996; Boucher and Pope 1996). May's survey effort in 1997 turned up a pair of spotted owls (May 1997).



The Tadpole #1 territory (MT #0607005) is located on the Gila National Forest north of Silver City, NM. The original territory size is 196 hectares (484 acres) and the addition of our 1-km radius circle increased our survey area to 359 ha (888 ac). The original territory ranges in elevation from 2,220 - 2,601 meters (7,283 - 8,533 feet) and lies predominately on north-facing slopes, with 70% of the territory having an aspect between 315°- 45°. The average slope over the territory is 22.7°. The Tadpole #1 territory was paired with the unburned Redstone #1 territory located approximately 11.5 kilometers to the southeast.

Along with the Tadpole #2 and the Tadpole #3 territories, the Tadpole #1 territory was burned in varying degrees by three separate fires, including a prescribed natural fire in 1992, the Glass fire in 1994 and the Q-ball prescribed natural fire in 1995. We had 57 habitat survey points within this original

territory boundary and 5% of these showed no evidence of recent fire. 46% showed only evidence of ground fire, 32% burned to some degree (but not completely) into the canopy and 18% showed complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 25% of the territory had a Pine cover type, 11% had a mixture of Pine and Oak, and 65% had a Mixed Conifer cover type. 0% was classified as "Other".

Spotted Owl Monitoring History for Tadpole #1 Territory (adapted from Boucher and Pope [1996])							
1990	1991	1992	1993	1994	1995	1996	***1997***
Single	Unknown	Single	Single	Unknown	Unknown	Unknown	***Single****
- Both a ♂ and ♀ spotted owl were located in 1997, but the ♂ was located approximately 800m west of the territory boundary and therefore was not counted as a *Tadpole #1 ♂*.							

The Tadpole #2 territory (MT #0607006) is located on the Gila National Forest north of Silver City, NM. The original territory size is 181 hectares (446 acres) and the addition of our 1-km radius circle increased our survey area to 366 ha (904 ac). The original territory ranges in elevation from 2,185 - 2,558 meters (7,169 - 8,392 feet) and lies predominately on north-facing slopes, with 77% of the territory having an aspect between 315°- 45°. The average slope over the territory is 14.8°. The Tadpole #2 territory was paired with the unburned Redstone #3 territory located approximately 6.5 kilometers to the east.

Along with the Tadpole #1 and the Tadpole #3 territories, the Tadpole #2 territory was burned in varying degrees by three separate fires, including a prescribed natural fire in 1992, the Glass fire in 1994 and the Q-ball prescribed natural fire in 1995. We had 50 habitat survey points within this original territory boundary and 6% of these showed no evidence of recent fire. 62% showed only evidence of ground fire, 26% burned to some degree (but not completely) into the canopy and 6% showed complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 18% of the territory had a Pine cover type, 26% had a mixture of Pine and Oak, and 50% had a Mixed Conifer cover type. 6% was classified as "Other".

Spotted Owl Monitoring History for Tadpole #2 Territory (adapted from Boucher and Pope [1996] and Personal Observation in 1996)							
1990	1991	1992	1993	1994	1995	1996	***1997***
Pair	Unknown	Pair	Pair	Unknown	Unknown	Nest (1 young)	***Pair***

The Tadpole #3 territory (MT #0607007) is located in the Gila National Forest north of Silver City, NM. The original territory size is 230 hectares (568 acres) and the addition of our 1-km radius circle increased our survey area to 414 ha (1,022 ac). The original territory ranges in elevation from 2,279 -

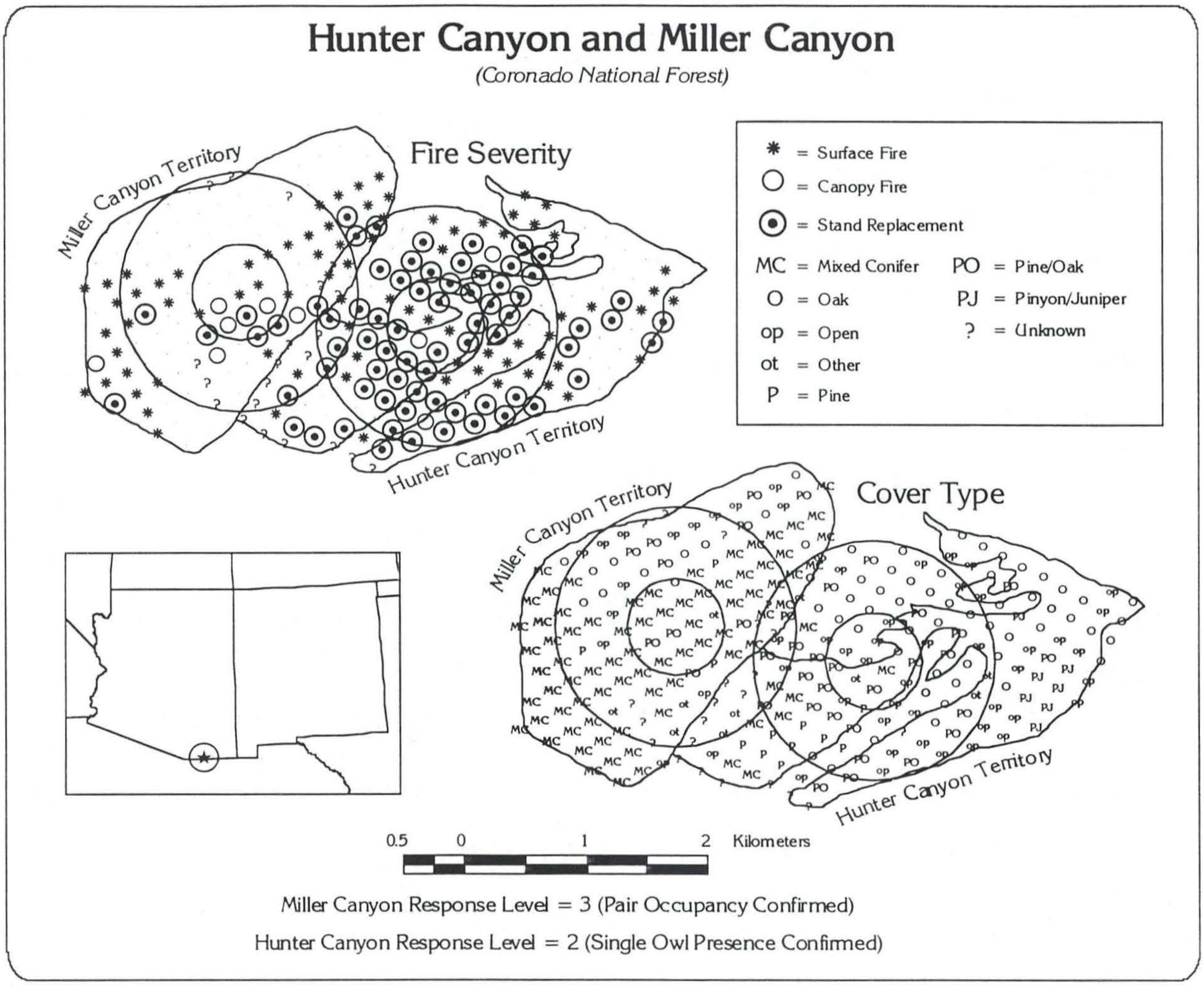
2,622 meters (7,477 - 8,602 feet) and lies predominately on north-facing slopes, with 69% of the territory having an aspect between 315°- 45°. The average slope over the territory is 20.7°. The Tadpole #3 territory was paired with the unburned McMillen territory located approximately 3.5 kilometers to the southeast.

Along with the Tadpole #1 and the Tadpole #2 territories, the Tadpole #3 territory was burned in varying degrees by three separate fires, including a prescribed fire in 1992, the Glass fire in 1994 and the Q-ball prescribed natural fire in 1995. We had 66 habitat survey points within this original territory boundary and 18% of these showed no evidence of recent fire. 50% showed only evidence of ground fire, 18% burned to some degree (but not completely) into the canopy and 14% showed complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 11% of the territory had a Pine cover type, 17% had a mixture of Pine and Oak, and 68% had a Mixed Conifer cover type. 5% was classified as "Other".

Spotted Owl Monitoring History for Tadpole #3 Territory (adapted from Boucher and Pope [1996])							
1990	1991	1992	1993	1994	1995	1996	***1997***
Pair	Unknown	Absent	Absent	Unknown	Unknown	Unknown	***Single***

Coronado Territories



The Hunter Canyon territory (MT #0503017) is located in the Huachuca Mountains of the Coronado National Forest, southwest of Sierra Vista, AZ. The original territory size is 355 hectares (877 acres) and the addition of our 1-km radius circle increased our survey area to 523 ha (1,293 ac). The original territory ranges in elevation from 1,590 - 2,844 meters (5,217 - 9,330 feet) and lies predominately on north-facing slopes, with 55% of the territory having an aspect between 315°- 45°. The average slope over the territory is 24.7°. The Hunter Canyon territory was paired with the unburned Lower Ash territory located approximately 1 kilometer to the south.

Along with the Miller Canyon territory, the Hunter Canyon territory was burned by the Hunter fire in 1994. We had 106 habitat survey points within this original territory boundary and 27% of these showed no evidence of recent fire. 21% showed only evidence of ground fire, 2% burned to some degree (but not completely) into the canopy and 39% showed complete stand replacement burn. 11% of the

survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 8% of the territory had a Pine cover type, 17% had a mixture of Pine and Oak, and 7% had a Mixed Conifer cover type. 58% was classified as "Other" and 11% was unknown.

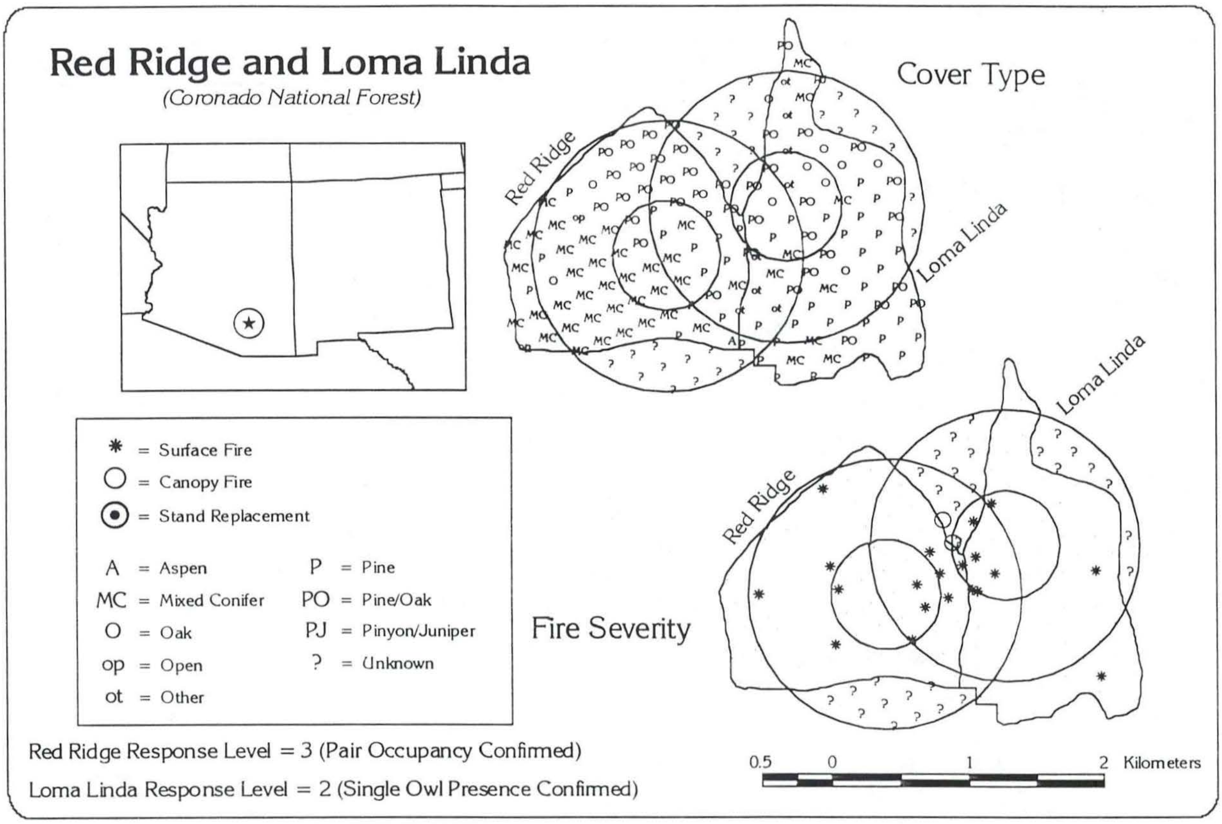
Spotted Owl Monitoring History for Hunter Canyon Territory (adapted from Duncan [1996] and Skinner [1996])			
1994	1995	1996	*1997*
Pair	Pair	Single	***Absent***

The Miller Canyon territory (MT #0503001) is located in the Huachuca Mountains of the Coronado National Forest, southwest of Sierra Vista, AZ. The original territory size is 423 hectares (1,045 acres) and the addition of our 1-km radius circle increased our survey area to 465 ha (1,149 ac). The original territory ranges in elevation from 1,788 - 2,883 meters (5,866 - 9,459 feet) and lies predominately on north-facing slopes, with 53% of the territory having an aspect between 315°- 45°. The average slope over the territory is 31.1°. The Miller Canyon territory was paired with the unburned Ramsey Canyon territory located approximately 1 kilometer to the northwest.

Along with the Hunter Canyon territory, the Miller Canyon territory was burned by the Hunter fire in 1994. We had 124 habitat survey points within this original territory boundary and 51% of these showed no evidence of recent fire. 31% showed only evidence of ground fire, 5% burned to some degree (but not completely) into the canopy and 8% showed complete stand replacement burn. 6% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 2% of the territory had a Pine cover type, 9% had a mixture of Pine and Oak, and 56% had a Mixed Conifer cover type. 27% was classified as "Other" and 6% was unknown.

Spotted Owl Monitoring History for Miller Canyon Territory (adapted from Duncan [1996] and Skinner [1996])							
1990	1991	1992	1993	1994	1995	1996	***1997***
Pair	Nest (1 young)	Nest (3 young)	Nest (1 young)	Single	Pair	Pair	***Pair***



The Loma Linda territory (MT #0505008) is located in the Santa Catalina mountains of the Coronado National Forest north of Tucson, AZ. The original territory size is 221 hectares (546 acres) and the addition of our 1-km radius circle increased our survey area to 364 ha (900 ac). The original territory ranges in elevation from 1,975 - 2,575 meters (6,479 - 8,448 feet) and lies predominately on west-facing slopes, with 45% of the territory having an aspect between 225°- 315°. The average slope over the territory is 26.8°. The Loma Linda territory was originally designated as an *unburned* territory, but was reclassified when owl surveyors found extensive signs of fire within the territory boundaries. The territory therefore has no unburned counterpart to pair it with.

Along with the Red Ridge territory, the Loma Linda territory was burned by a recent fire which probably occurred in 1995 or 1996. I was unable to determine the name of this fire. We had 69 habitat survey points within this original territory boundary and 90% of these showed no evidence of recent fire. 10% showed only evidence of ground fire and no points showed any sign of canopy or complete stand replacement burn. 0% of the survey points within the original territory boundary were inaccessible or otherwise not surveyed.

Prior to the fire, 39% of the territory had a Pine cover type, 26% had a mixture of Pine and Oak, and 13% had a Mixed Conifer cover type. 1% was classified as "Other".

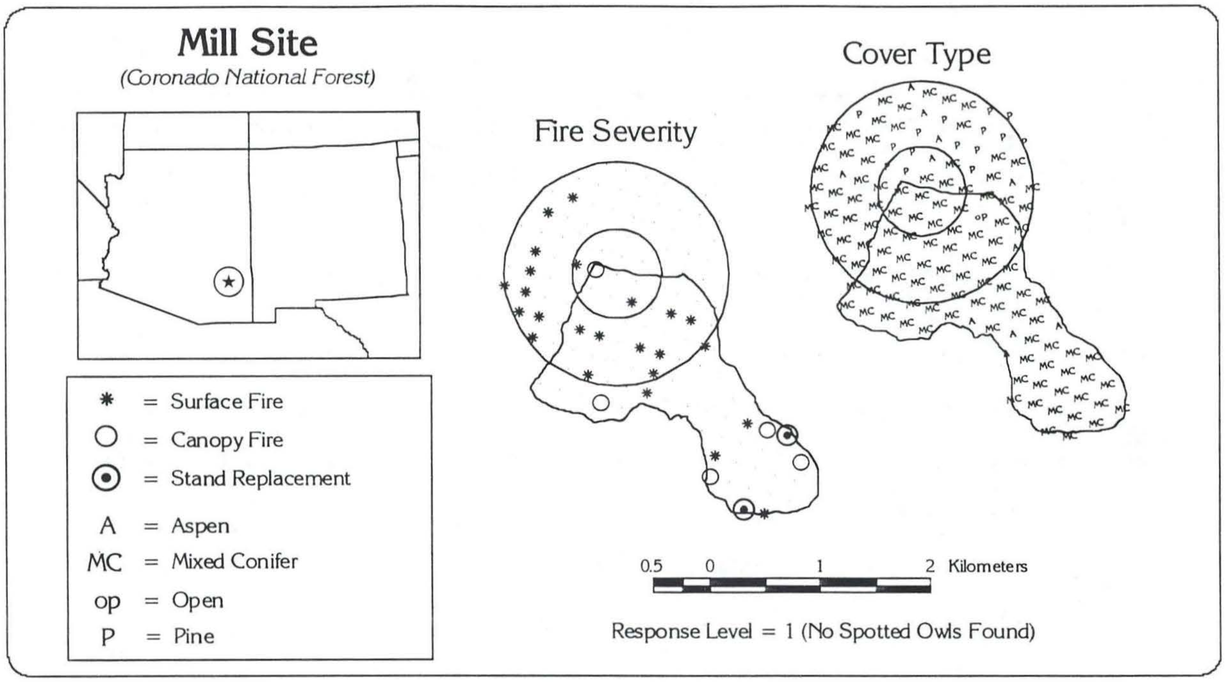
Spotted Owl Monitoring History for Loma Linda Territory (adapted from Bieber [1996] and Duncan [1996])								
1989	1990	1991	1992	1993	1994	1995	1996	***1997***
Single	Single	Pair	Nest (2 young)	Nest (2 young)	Pair	Pair	Not Surveyed	***Single***

The Red Ridge territory (MT #0505014) is located in the Santa Catalina mountains of the Coronado National Forest north of Tucson, AZ. The original territory size is 237 hectares (585 acres) and the addition of our 1-km radius circle increased our survey area to 337 ha (832 ac). The original territory ranges in elevation from 1,859 - 2,504 meters (6,099 - 8,215 feet) and lies predominately on north-facing slopes, with 55% of the territory having an aspect between 315°- 45°. The average slope over the territory is 25.0°. The Red Ridge territory was originally designated as an *unburned* territory, but was reclassified when owl surveyors found extensive signs of fire within the territory boundaries. The territory therefore has no unburned counterpart to pair it with.

Along with the Loma Linda territory, the Red Ridge territory was burned by a recent fire which probably occurred in 1995 or 1996. I was unable to determine the name of this fire. We had 71 habitat survey points within this original territory boundary and 83% of these showed no evidence of recent fire. 17% showed only evidence of ground fire, and no points showed any sign of canopy or complete stand replacement burn. 0% of the survey points within the original territory boundary were inaccessible or otherwise not surveyed.

Prior to the fire, 20% of the territory had a Pine cover type, 24% had a mixture of Pine and Oak, and 48% had a Mixed Conifer cover type. 8% was classified as "Other".

Spotted Owl Monitoring History for Red Ridge Territory (adapted from Duncan [1996] and Skinner [1996])							
1990	1991	1992	1993	1994	1995	1996	***1997***
Pair	Pair	Nest (1 young)	Pair	Pair	Pair	Unknown	***Pair***



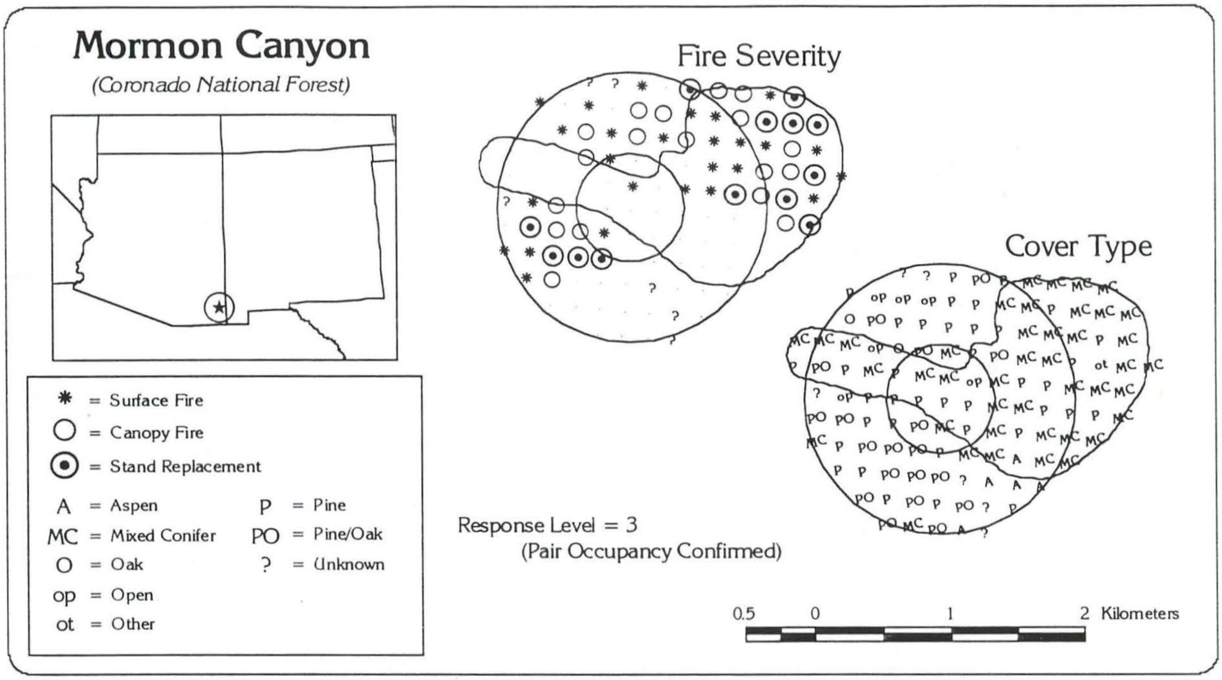
The Mill Site territory (MT #0504007) is located in the Pinaleno Mountains of the Coronado National Forest, southwest of Safford, AZ. The original territory size is 267 hectares (660 acres) and the addition of our 1-km radius circle increased our survey area to 466 ha (1,152 ac). The original territory ranges in elevation from 2,621 - 3,147 meters (8,599 - 10,325 feet) and lies predominately on north-facing slopes, with 42% of the territory having an aspect between 315°- 45°. The average slope over the territory is 19.6°. The Mill Site territory was paired with the unburned Ash Creek territory located approximately 300 meters to the east.

Along with the Upper Cunningham, Webb Peak and Riggs Lake territories, the Mill Site territory was burned by the Clark Peak fire in 1996. We had 74 habitat survey points within this original territory boundary and 73% of these showed no evidence of recent fire. 18% showed only evidence of ground fire, 7% burned to some degree (but not completely) into the canopy and 3% showed complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 0% of the territory had a Pine cover type, 0% had a mixture of Pine and Oak, and 92% had a Mixed Conifer cover type. 8% was classified as "Other".

Spotted Owl Monitoring History for Mill Site Territory (adapted from Froehlich and McCluhan [1996] and Duncan [1996])

1990	1991	1992	1993	1994	1995	1996	***1997***
Pair	Pair	Pair	Pair	Unknown	Unknown	Not Surveyed	***Absent***

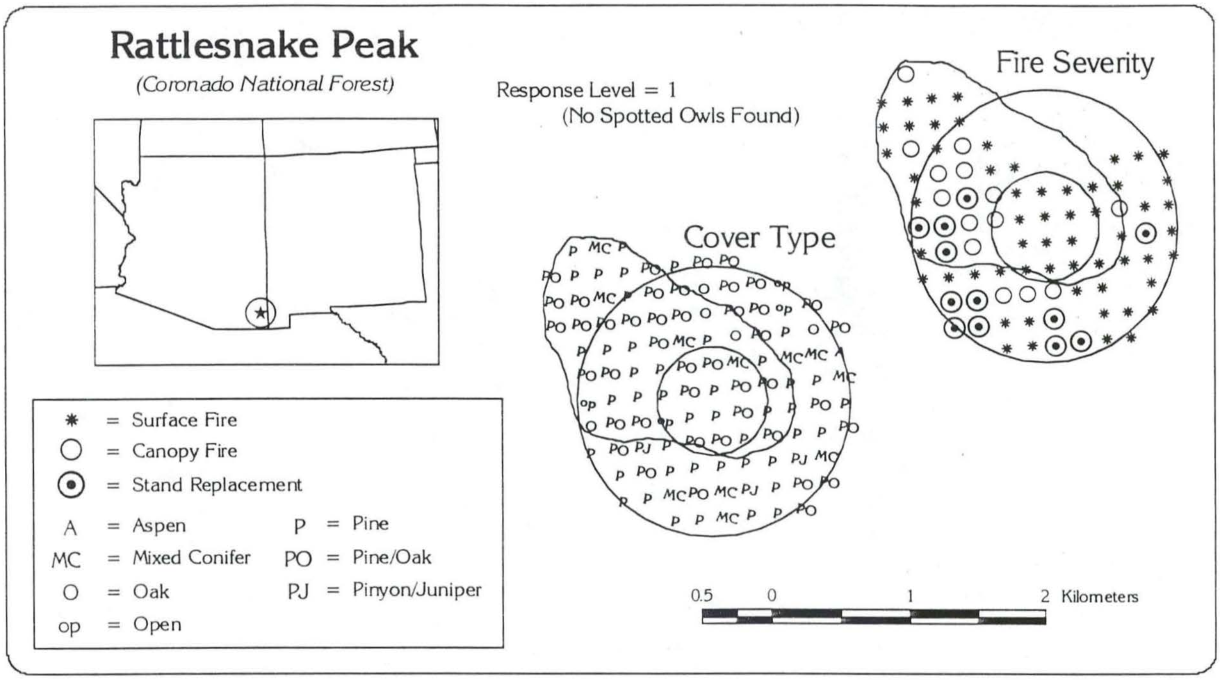


The Mormon Canyon territory (MT #0501008) is located in the Chiricahua Mountains of the Coronado National Forest, west of Portal, AZ. The original territory size is 206 hectares (510 acres) and the addition of our 1-km radius circle increased our survey area to 387 ha (957 ac). The original territory ranges in elevation from 2,131 - 2,817 meters (6,991 - 9,242 feet) and lies predominately on north- and west-facing slopes, with 51% of the territory having an aspect between 315°- 45° and 40% between 225°- 315°. The average slope over the territory is 27.4°. The Mormon Canyon territory was paired with the unburned Sunny Flat territory located approximately 10 kilometers to the northeast.

Along with the Rattlesnake Peak and Rucker Canyon territories, the Mormon Canyon territory was burned by the Rattlesnake fire in 1995. We had 61 habitat survey points within our original territory boundary and 49% of these showed no evidence of recent fire. 21% showed only evidence of ground fire, 16% burned to some degree (but not completely) into the canopy and 13% showed complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 30% of the territory had a Pine cover type, 3% had a mixture of Pine and Oak, and 59% had a Mixed Conifer cover type. 8% was classified as "Other".

Spotted Owl Monitoring History for Mormon Canyon Territory (adapted from Duncan [1996] and Helbing [1996])							
1985	1986-1991	1992	1993	1994	1995	1996	***1997***
Pair	Not Surveyed	Pair	Not Surveyed	Not Surveyed	Not Surveyed	Not Surveyed	***Pair***



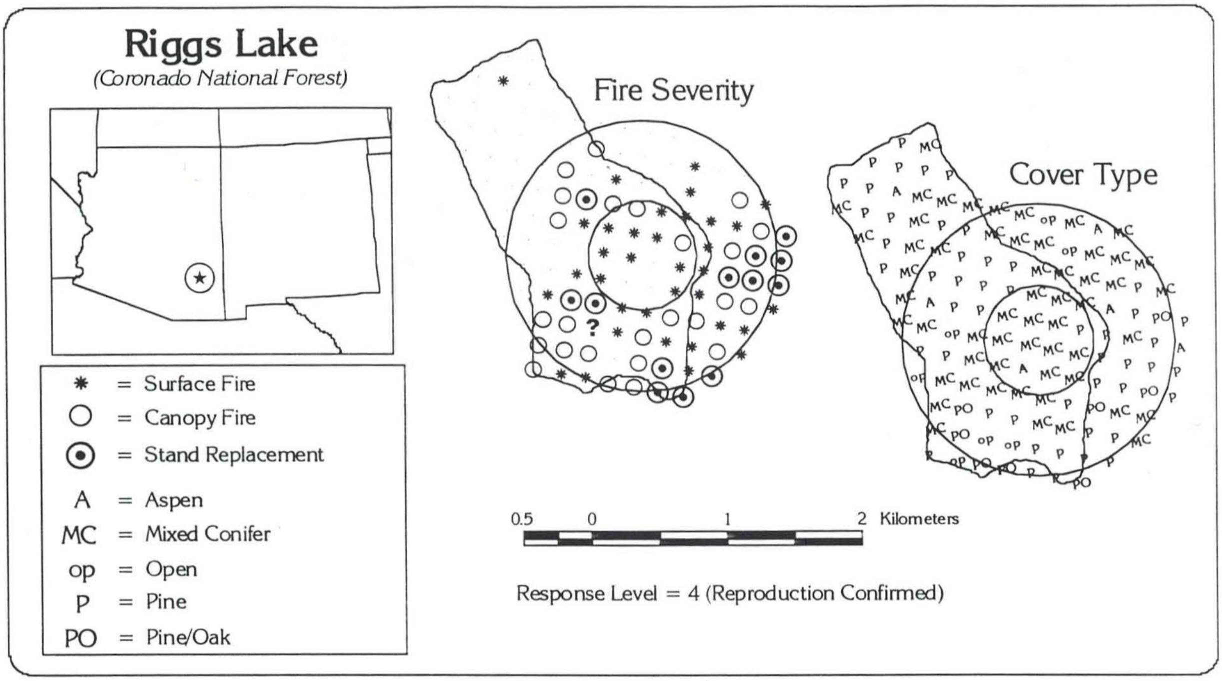
The Rattlesnake Peak territory (MT #0501013) is located in the Chiricahua Mountains of the Coronado National Forest, west of Portal, AZ. The original territory size is 202 hectares (498 acres) and the addition of our 1-km radius circle increased our survey area to 362 ha (896 ac). The original territory ranges in elevation from 1,968 - 2,415 meters (6,457 - 7,923 feet) and lies predominately on north-facing slopes, with 43% of the territory having an aspect between 315° - 45°. The average slope over the territory is 25.0°. The Rattlesnake Peak territory was paired with the unburned Barfoot territory located approximately 2 kilometers to the northeast.

Along with the Mormon Canyon and Rucker Canyon territories, the Rattlesnake Peak territory was burned by the Rattlesnake fire in 1995. We had 59 habitat survey points within our original territory boundary and 22% of these showed no evidence of recent fire. 53% showed only evidence of ground fire, 19% burned to some degree (but not completely) into the canopy and 7% showed complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 39% of the territory had a Pine cover type, 46% had a mixture of Pine and Oak, and 7% had a Mixed Conifer cover type. 8% was classified as "Other".

Spotted Owl Monitoring History for Rattlesnake Peak Territory (adapted from Duncan [1996] and Helbing [1996])

1982	1983-1991	1992	1993	1994	1995	1996	***1997***
Single	Not Surveyed	Nest (2 young)	Nest (1 young)	Not Surveyed	Not Surveyed	Not Surveyed	***Absent***



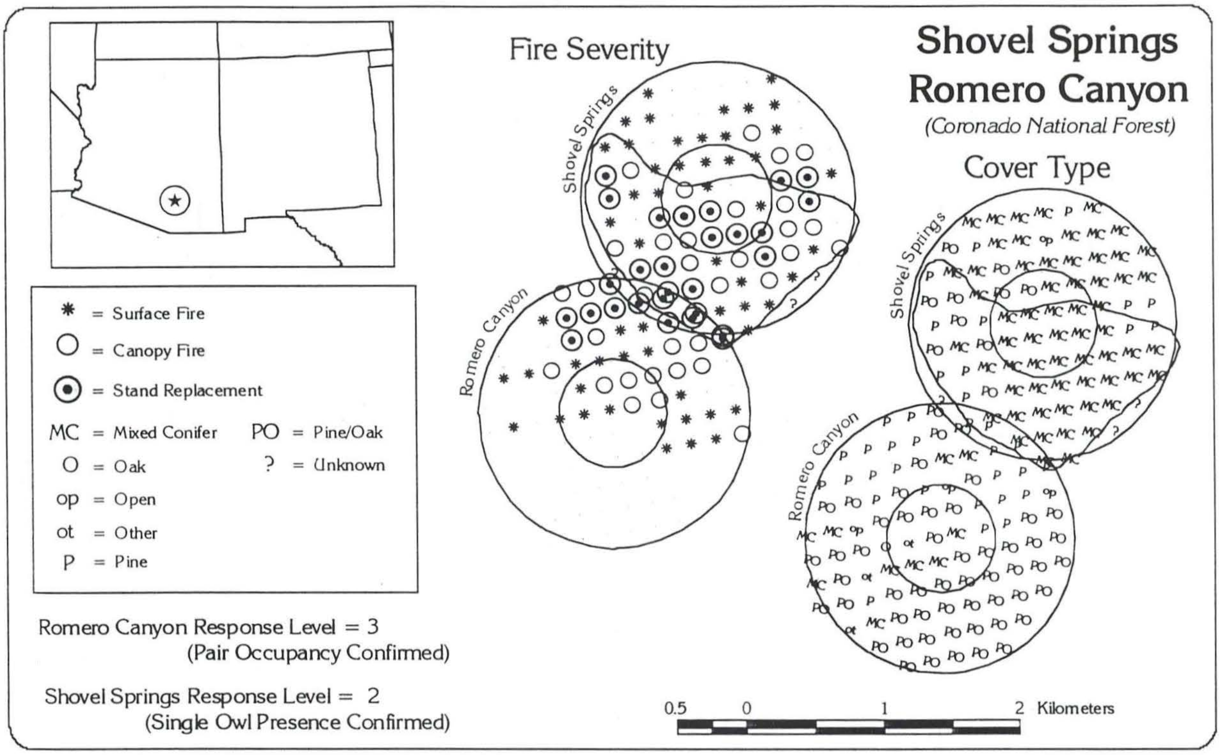
The Riggs Lake territory (MT #0504003) is located in the Pinaleno Mountains of the Coronado National Forest, southwest of Safford, AZ. The original territory size is 285 hectares (703 acres) and the addition of our 1-km radius circle increased our survey area to 405 ha (1,001 ac). The original territory ranges in elevation from 2,484 - 2,829 meters (8,150 - 9,281 feet) and lies predominately on south- and west-facing slopes, with 28% of the territory having an aspect between 135°- 225° and 35% of the territory having an aspect between 225°- 315°. The average slope over the territory is 14.4°. The Riggs Lake territory was paired with the unburned Grant Hill territory located approximately 6 kilometers to the southeast.

Along with the Upper Cunningham, Webb Peak and Mill Site territories, the Riggs Lake territory was burned by the Clark Peak fire in 1996. We had 83 habitat survey points within this original territory boundary and 46% of these showed no evidence of recent fire. 28% showed only evidence of ground fire, 19% burned to some degree (but not completely) into the canopy and 6% showed complete stand replacement burn. 1% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 41% of the territory had a Pine cover type, 4% had a mixture of Pine and Oak, and 47% had a Mixed Conifer cover type. 7% was classified as "Other" and 1% was unknown.

Spotted Owl Monitoring History for Riggs Lake Territory (adapted from Duncan [1996] and Froehlich and McCluhan [1996])							
1990	1991	1992	1993	1994	1995	1996	*1997*
Pair	Nest (3 young)	Nest (3 young)	Single	Single	Pair	Not Surveyed	***Nest (2 Young)*** ***See note next page...*** →

Our survey effort in 1997 turned up a reproducing pair of spotted owls with two fledglings. However, it should be mentioned that this pair was located close to the border of the Chesley Flat territory, which was also badly burned, and it is possible that we found the Chesley Flat pair. I chose to consider the Riggs Lake territory as Reproductive because we found the owls within our survey area and I feel that there is a very good chance that these owls are the Riggs Lake birds.



The Romero Canyon territory (MT #0505018) is located in the Santa Catalina Mountains of the Coronado National Forest, north of Tucson, AZ. I could find no records of an original territory delineation so I used the 1-km radius circle as the complete survey area. This 1-km circle is 313 hectares (772 acres) in size. The original territory ranges in elevation from 2,034 - 2,597 meters (6,673 - 8,520 feet) and lies predominately on south- and west-facing slopes, with 30% of the territory having an aspect between 135°- 225° and 45% between 225°- 315°. The average slope over the territory is 23.0°. The Romero Canyon territory was originally intended to be paired with the Loma Linda territory, but we found evidence of fire in Loma Linda midway through the project and I had to leave Romero Canyon unpaired.

Along with the Shovel Springs territory, the Romero Canyon territory was burned by the Shovel fire in 1994. We had 98 habitat survey points within our 1-km circle and 49% of these showed no evidence of recent fire. 22% showed only evidence of ground fire, 15% burned to some degree (but not completely) into the canopy and 13% showed complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 26% of the territory had a Pine cover type, 54% had a mixture of Pine and Oak, and 13% had a Mixed Conifer cover type. 7% was classified as "Other".

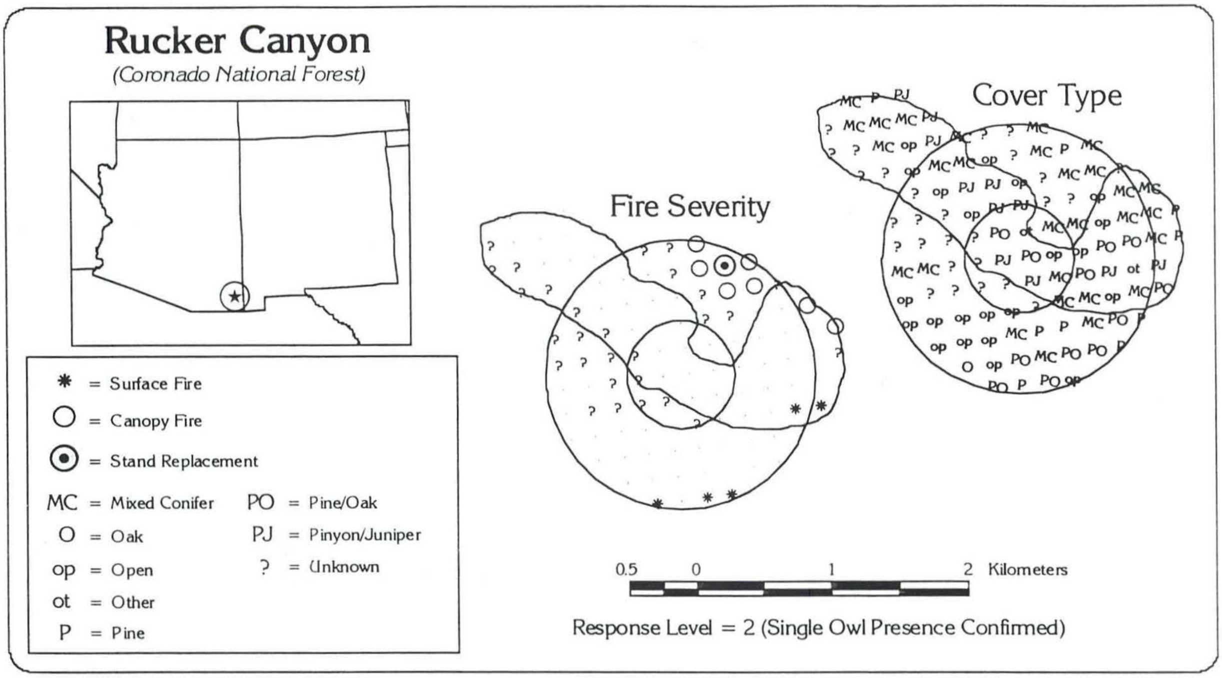
Spotted Owl Monitoring History for Romero Canyon Territory (adapted from Bieber [1996] and Duncan [1996])			
1994	1995	1996	*1997*
Single	Pair	Not Surveyed	***Pair***

The Shovel Springs territory (MT #0505013) is located in the Santa Catalina Mountains of the Coronado National Forest, north of Tucson, AZ. The original territory size is 174 hectares (429 acres) and the addition of our 1-km radius circle increased our survey area to 315 ha (778 ac). The original territory ranges in elevation from 2,114 - 2,691 meters (6,935 - 8,829 feet) and lies predominately on north- and west-facing slopes, with 39% of the territory having an aspect between 315°- 45° and 41% between 225°- 315°. The average slope over the territory is 26.7°. The Shovel Springs territory was originally intended to be paired with the Red Ridge territory, but we found evidence of fire in Red Ridge midway through the project and I had to leave Shovel Springs unpaired.

Along with the Romero Canyon territory, the Shovel Springs territory was burned by the Shovel fire in 1994. We had 54 habitat survey points within our original territory boundary and 7% of these showed no evidence of recent fire. 28% showed only evidence of ground fire, 30% burned to some degree (but not completely) into the canopy and 35% showed complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 20% of the territory had a Pine cover type, 11% had a mixture of Pine and Oak, and 69% had a Mixed Conifer cover type. 7% was classified as "Other".

Spotted Owl Monitoring History for Shovel Springs Territory (adapted from Bieber [1996] and Duncan [1996])								
1989	1990	1991	1992	1993	1994	1995	1996	*1997*
Nest (1 young)	Single	Not Surveyed	Nest (2 young)	Pair	Pair	Pair	Not Surveyed	***Single***



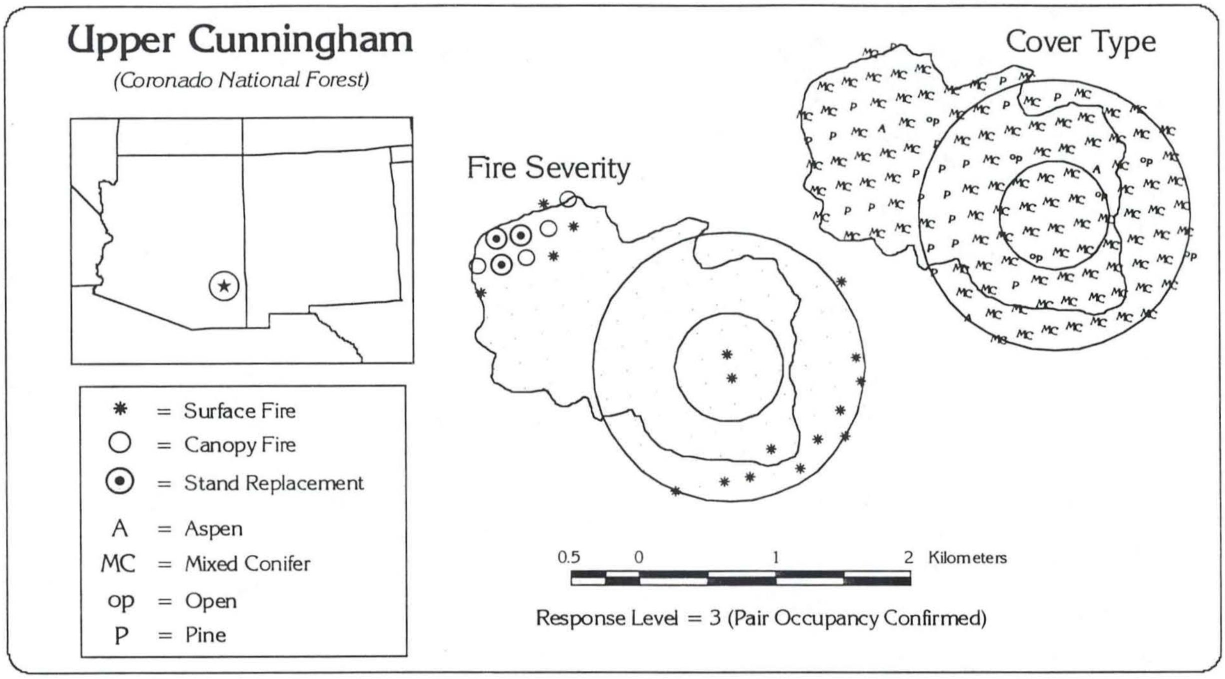
The Rucker Canyon territory (MT #0501009) is located in the Chiricahua Mountains of the Coronado National Forest, west of Portal, AZ. The original territory size is 188 hectares (464 acres) and the addition of our 1-km radius circle increased our survey area to 378 ha (935 ac). The original territory ranges in elevation from 2,009 - 2,475 meters (6,591 - 8,120 feet) and has a fairly equal distribution of north-, east-, south- and west-facing slopes. The average slope over the territory is 32.3°. The Rucker Canyon territory was paired with the unburned Dobson Peak territory located approximately 3 kilometers to the south.

Along with the Mormon Canyon and Rattlesnake Peak territories, the Rucker Canyon territory was burned by the Rattlesnake fire in 1995. We had 56 habitat survey points within our original territory boundary and 75% of these showed no evidence of recent fire. 4% showed only evidence of ground fire, 4% burned to some degree (but not completely) into the canopy and 0% showed complete stand replacement burn. 18% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 5% of the territory had a Pine cover type, 11% had a mixture of Pine and Oak, and 30% had a Mixed Conifer cover type. 36% was classified as "Other" and 18% was unknown.

Spotted Owl Monitoring History for Rucker Canyon Territory (adapted from Duncan [1996] and Helbing [1996])

1985	1986-1990	1991	1992	1993	1994	1995	1996	*1997*
Single	Not Surveyed	Nest (2 young)	Absent	Nest (2 young)	Not Surveyed	Not Surveyed	Not Surveyed	***Single***



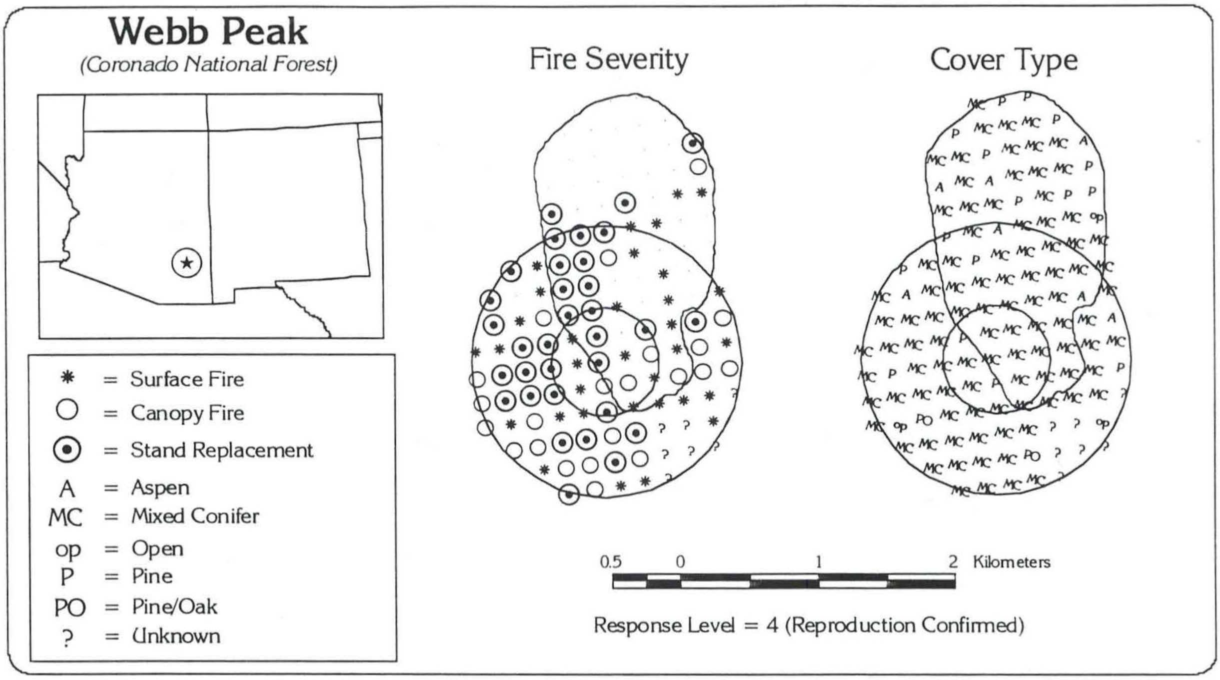
The Upper Cunningham territory (MT #0504013) is located in the Pinaleno Mountains of the Coronado National Forest, southwest of Safford, AZ. The original territory size is 329 hectares (812 acres) and the addition of our 1-km radius circle increased our survey area to 446 ha (1,103 ac). The original territory ranges in elevation from 2,657 - 2,999 meters (8,717 - 9,839 feet) and lies predominately on south- and west-facing slopes, with 41% of the territory having an aspect between 135°- 225° and 40% of the territory having an aspect between 225°- 315°. The average slope over the territory is 21.1°. The Upper Cunningham territory was paired with the unburned Hagens Point territory located approximately 3.5 kilometers to the south.

Along with the Mill Site, Webb Peak and Riggs Lake territories, the Upper Cunningham territory was burned by the Clark Peak fire in 1996. We had 97 habitat survey points within this original territory boundary and 87% of these showed no evidence of recent fire. 6% showed only evidence of ground fire, 4% burned to some degree (but not completely) into the canopy and 3% showed complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 19% of the territory had a Pine cover type, 0% had a mixture of Pine and Oak, and 75% had a Mixed Conifer cover type. 6% was classified as "Other".

Spotted Owl Monitoring History for Upper Cunningham Territory (adapted from Duncan [1996] and Froehlich and McCluhan [1996])

1990	1991	1992	1993	1994	1995	1996	***1997***
Pair	Single	Single	Not Surveyed	Not Surveyed	Pair	Nest (2 young)	***Pair***



The Webb Peak territory (MT #0504006) is located in the Pinaleno Mountains of the Coronado National Forest, southwest of Safford, AZ. The original territory size is 230 hectares (570 acres) and the addition of our 1-km radius circle increased our survey area to 430 ha (1,063 ac). The original territory ranges in elevation from 2,609 - 3,047 meters (8,560 - 9,997 feet) and lies predominately on east-, south- and west-facing slopes, with 28% of the territory having an aspect between 225°- 315°, 32% between 135°- 225° and 37% of the territory between 45°- 135°. The average slope over the territory is 14.8°. The Webb Peak territory was paired with the unburned Lefthand Canyon territory located approximately 400 meters to the north.

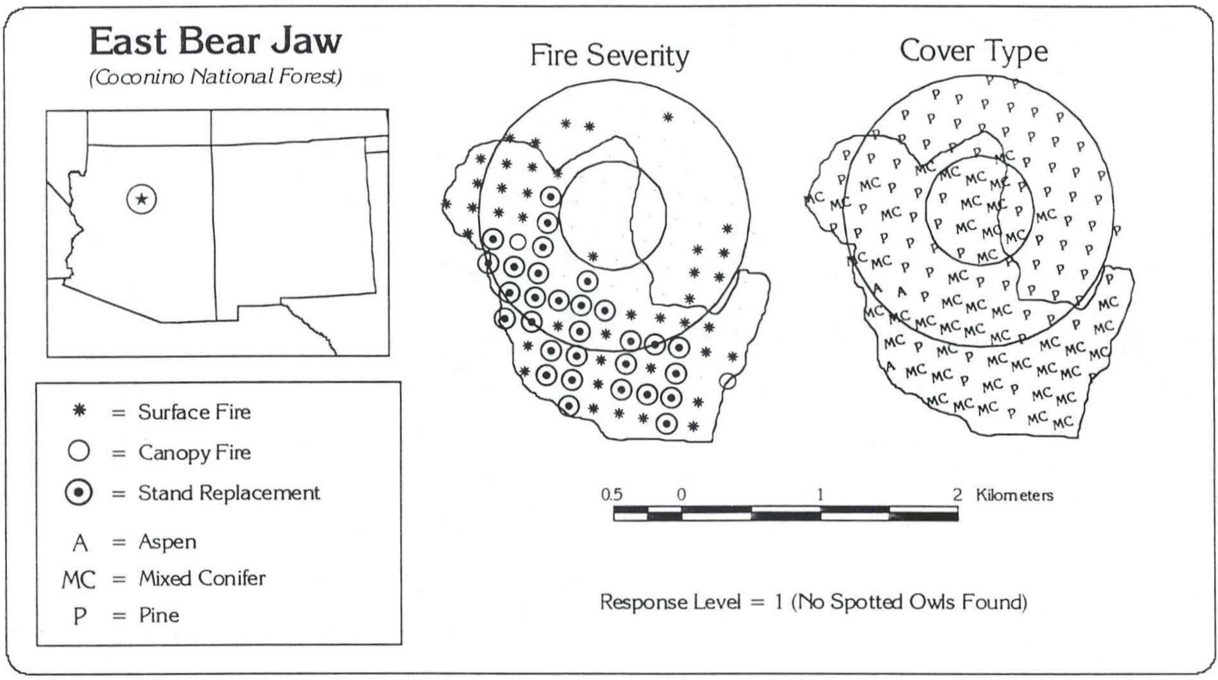
Along with the Mill Site, Upper Cunningham and Riggs Lake territories, the Webb Peak territory was burned by the Clark Peak fire in 1996. We had 66 habitat survey points within this original territory boundary and 50% of these showed no evidence of recent fire. 20% showed only evidence of ground fire, 8% burned to some degree (but not completely) into the canopy and 23% showed complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 17% of the territory had a Pine cover type, 0% had a mixture of Pine and Oak, and 74% had a Mixed Conifer cover type. 9% was classified as "Other".

Spotted Owl Monitoring History for Webb Peak Territory (adapted from Duncan [1996] and Froehlich and McCluhan [1996])

1990	1991	1992	1993	1994	1995	1996	*1997*
Pair	Not Surveyed	Single	Not Surveyed	Not Surveyed	Pair	Pair	*Nest (2 young)*

Coconino Territories



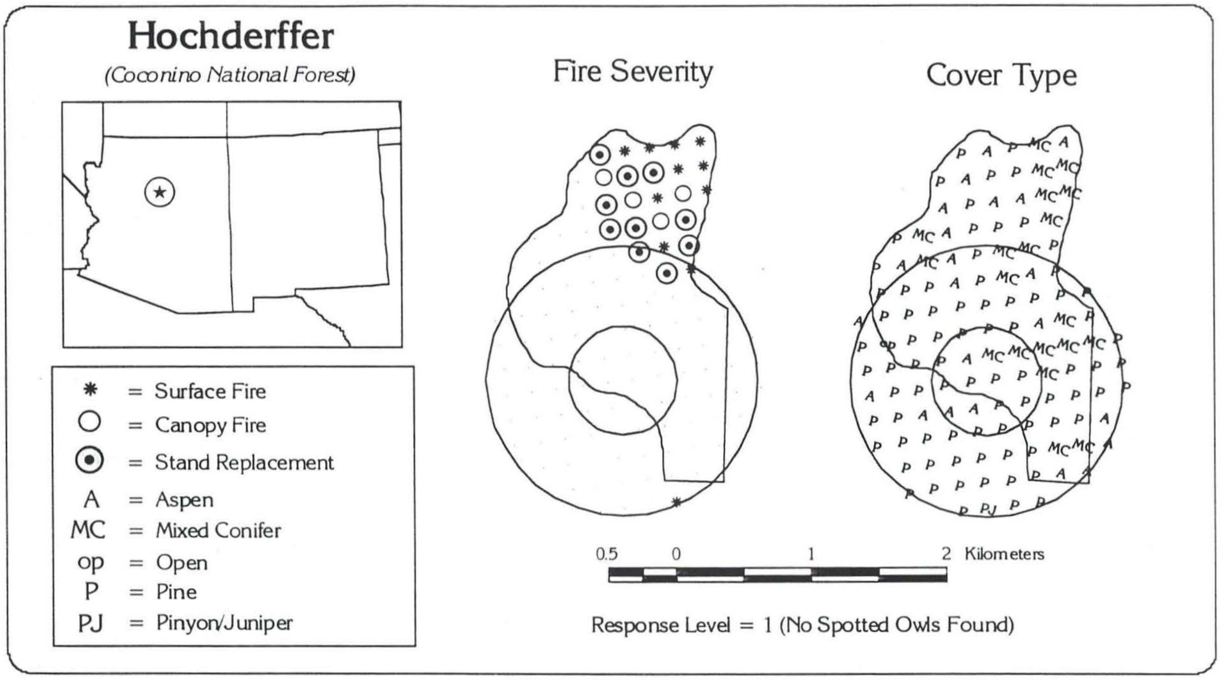
The East Bear Jaw territory (MT #040233) is located on the Coconino National Forest north of Flagstaff, AZ. The original territory size is 301 hectares (743 acres) and the addition of our 1-km radius circle increased our survey area to 449 ha (1,109 ac). The original territory ranges in elevation from 2,357 - 2,660 meters (7,732 - 8,727 feet) and lies predominately on east-facing slopes, with 43% of the territory having an aspect between 225°- 315°. The average slope over the territory is 16.1°. The East Bear Jaw territory was paired with the unburned Weatherford territory located 8 kilometers to the south.

The East Bear Jaw territory was burned by the Bear Jaw fire in 1995. We had 84 habitat survey points within this original territory boundary and 26% of these showed no evidence of recent fire. 37% showed only evidence of ground fire, 1% burned to some degree (but not completely) into the canopy and 36% showed complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 40% of the territory had a Pine cover type, 0% had a mixture of Pine and Oak, and 56% had a Mixed Conifer cover type. 4% was classified as "Other".

Spotted Owl Monitoring History for East Bear Jaw Territory (adapted from Randall-Parker [1996])		
1995*	1996	***1997***
Pair	Not Surveyed	***Absent***

- A pair of spotted owls was recorded on the East Bear Jaw territory in May 1995, 2 months prior to the beginning of the fire (Randall-Parker 1996).

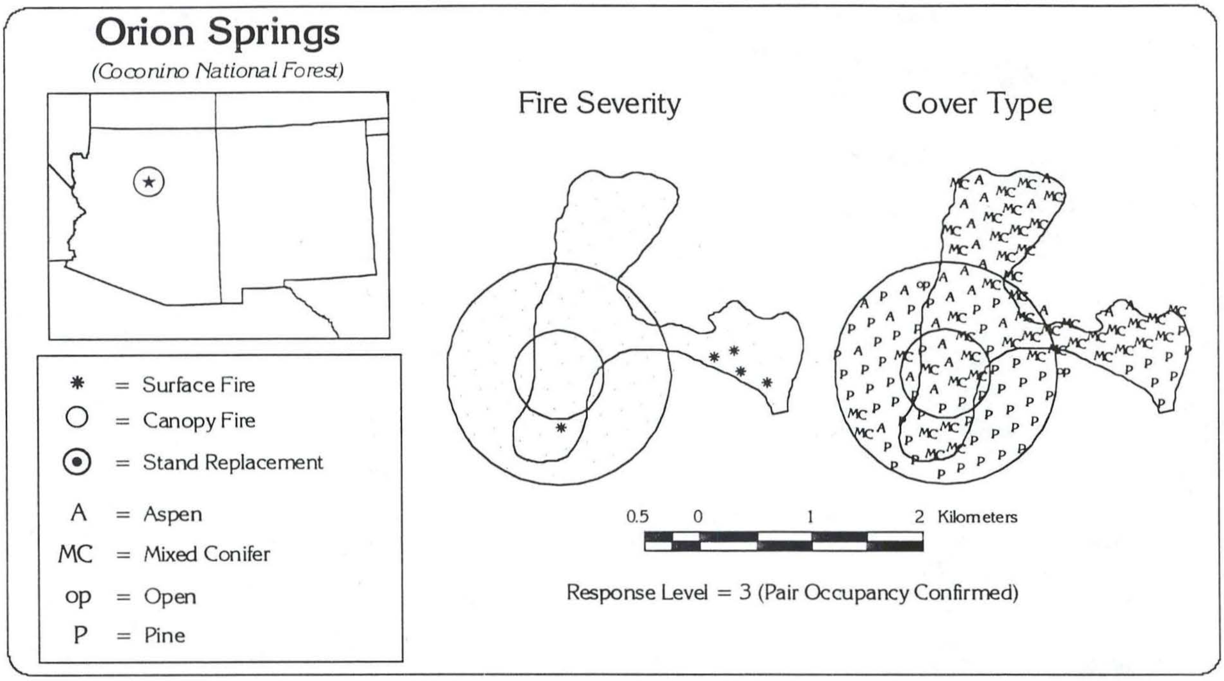


The Hochderffer territory (MT #040232) is located on the Coconino National Forest north of Flagstaff, AZ. The original territory size is 270 hectares (668 acres) and the addition of our 1-km radius circle increased our survey area to 412 ha (1,018 ac). The original territory ranges in elevation from 2,459 - 2,782 meters (8,068 - 9,128 feet) and lies predominately on west-facing slopes, with 49% of the territory having an aspect between 45°- 135°. The average slope over the territory is 15.5°. The Hochderffer territory was paired with the unburned Little Spring territory located approximately 2 kilometers to the east.

The Hochderffer territory was burned by the Hochderffer fire in 1996. We had 80 habitat survey points within this original territory boundary and 71% of these showed no evidence of recent fire. 11% showed only evidence of ground fire, 5% burned to some degree (but not completely) into the canopy and 13% showed complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 56% of the territory had a Pine cover type, 0% had a mixture of Pine and Oak, and 24% had a Mixed Conifer cover type. 20% was classified as "Other".

Spotted Owl Monitoring History for Hochderffer Territory (adapted from Randall-Parker [1996])			
1994	1995	1996	***1997***
Single	Single	Absent	***Absent***

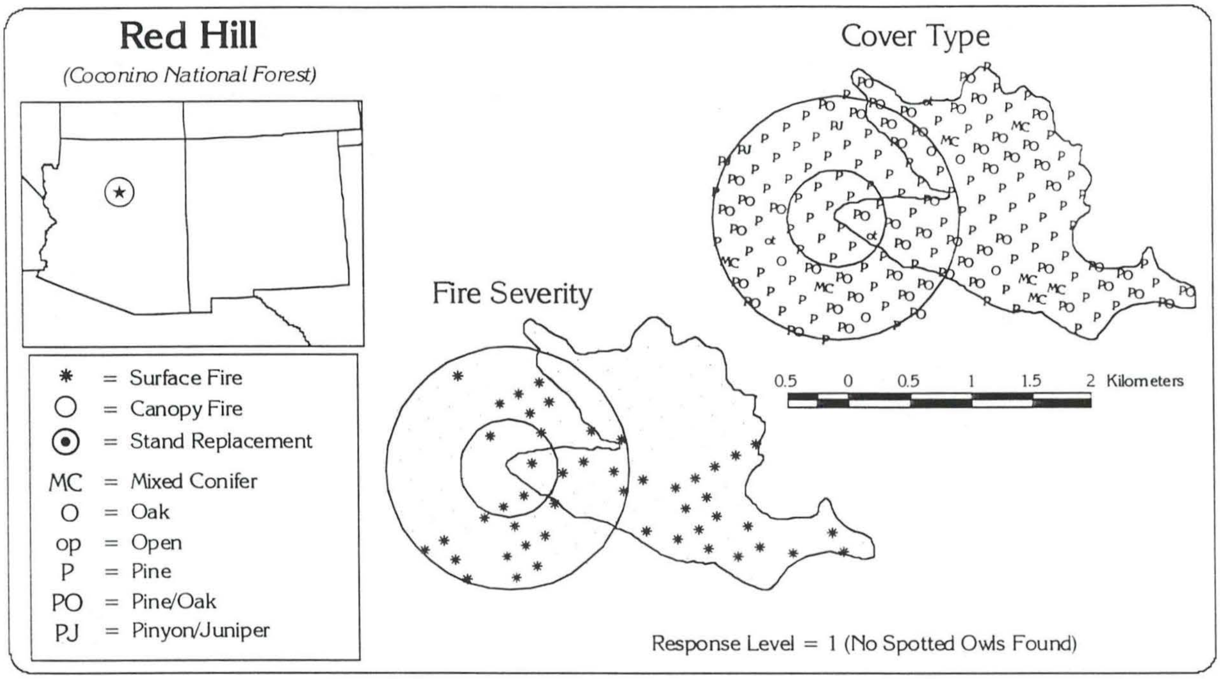


The Orion Springs territory (MT #040207) is located on the Coconino National Forest north of Flagstaff, AZ. The original territory size is 260 hectares (642 acres) and the addition of our 1-km radius circle increased our survey area to 452 ha (1,116 ac). The original territory ranges in elevation from 2,451 - 2,907 meters (8,041 - 9,537 feet) and lies predominately on south-facing slopes, with 58% of the territory having an aspect between 135°- 225°. The average slope over the territory is 13.2°. The Orion Springs territory was paired with the unburned Pipeline territory located 3.5 kilometers to the northeast.

The Orion Springs territory was burned by the some slopover from the Little Eldon Prescribed Fire in 1996 (Sheppard 1996). We had 75 habitat survey points within this original territory boundary and 93% of these showed no evidence of recent fire. 7% showed only evidence of ground fire and no points showed any sign of canopy or complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 25% of the territory had a Pine cover type, 0% had a mixture of Pine and Oak, and 49% had a Mixed Conifer cover type. 25% was classified as "Other".

Spotted Owl Monitoring History for Orion Springs Territory (adapted from Randall-Parker [1996])										
1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	***1997***
Pair	Pair	Nest (2 young)	Nest (1 young)	Pair	Nest (2 young)	Nest (1 young)	Pair	Not Surveyed	Single	***Pair***

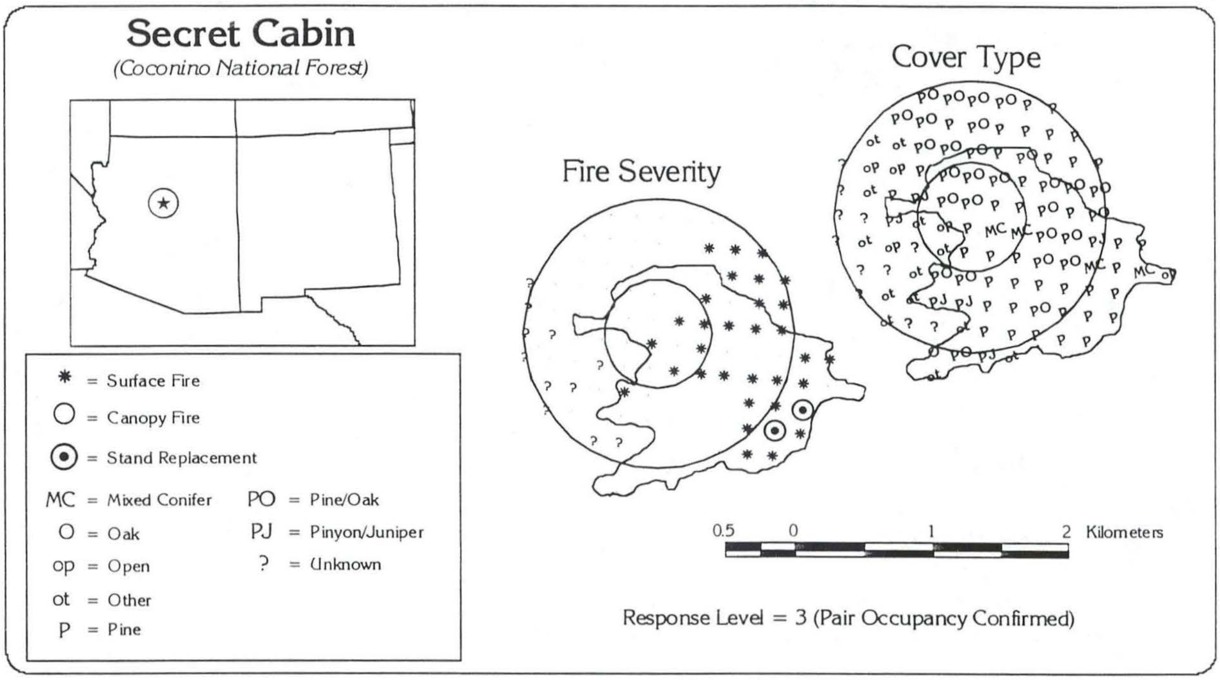


The Red Hill territory (MT #040224) is located on the Coconino National Forest southwest of Flagstaff, AZ. The original territory size is 305 hectares (753 acres) and the addition of our 1-km radius circle increased our survey area to 552 ha (1,365 ac). The original territory ranges in elevation from 1,945 - 2,224 meters (6,381 - 7,297 feet) and has a fairly equal distribution of north-, east-, south- and west-facing slopes. The average slope over the territory is 14.6°. The Red Hill territory was paired with the unburned Bunker Hill territory located approximately 7 kilometers to the south.

Along with the Upper West Fork territory, the Red Hill territory was burned by the Hog/Red Hill Prescribed Fire in 1994 (Peaks 1996). Red Hill was also burned fairly severely in 1988 during another phase of the same Red Hill Prescribed Fire project, before the Forest Service was aware that there were spotted owls in the area (Peaks 1990). We had 88 habitat survey points within this original territory boundary and 72% of these showed no evidence of recent fire. 28% showed only evidence of ground fire and no points showed any sign of canopy or complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 50% of the territory had a Pine cover type, 40% had a mixture of Pine and Oak, and 6% had a Mixed Conifer cover type. 5% was classified as "Other".

Spotted Owl Monitoring History for Red Hill Territory (adapted from Randall-Parker [1996])							
1990	1991	1992	1993	1994	1995	1996	***1997***
Single	Pair	Absent	Absent	Single	Not Surveyed	Not Surveyed	***Absent***

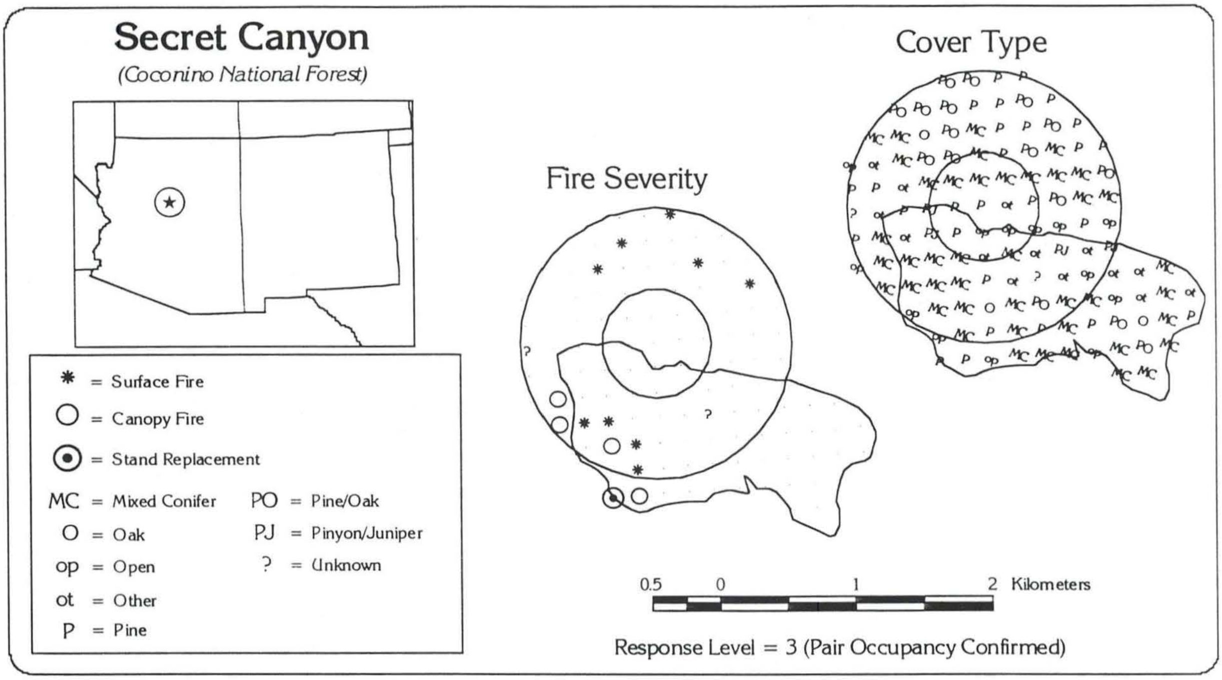


The Secret Cabin territory (MT #040222) is located on the Coconino National Forest southwest of Flagstaff, AZ. The original territory size is 199 hectares (493 acres) and the addition of our 1-km radius circle increased our survey area to 363 ha (953 ac). The original territory ranges in elevation from 1,826 - 2,005 meters (5,990 - 6,578 feet) and has a fairly equal distribution of north-, east-, south- and west-facing slopes. The average slope over the territory is 13.3°. The Secret Cabin territory was paired with the unburned Hidden Cabin territory located approximately 1 kilometer to the north.

Along with the Secret Canyon and Secret Mountain territories, the Secret Cabin territory was burned by the Lost fire in 1994. We had 58 habitat survey points within this original territory boundary and 55% of these showed no evidence of recent fire. 41% showed only evidence of ground fire, 0% burned to some degree (but not completely) into the canopy and 3% showed complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 48% of the territory had a Pine cover type, 33% had a mixture of Pine and Oak, and 7% had a Mixed Conifer cover type. 12% was classified as "Other".

Spotted Owl Monitoring History for Secret Cabin Territory (adapted from Randall-Parker [1996])							
1990	1991	1992	1993	1994	1995	1996	***1997***
Single	Nest (2 young)	Not Surveyed	Pair	Pair	Not Surveyed	Not Surveyed	***Pair***

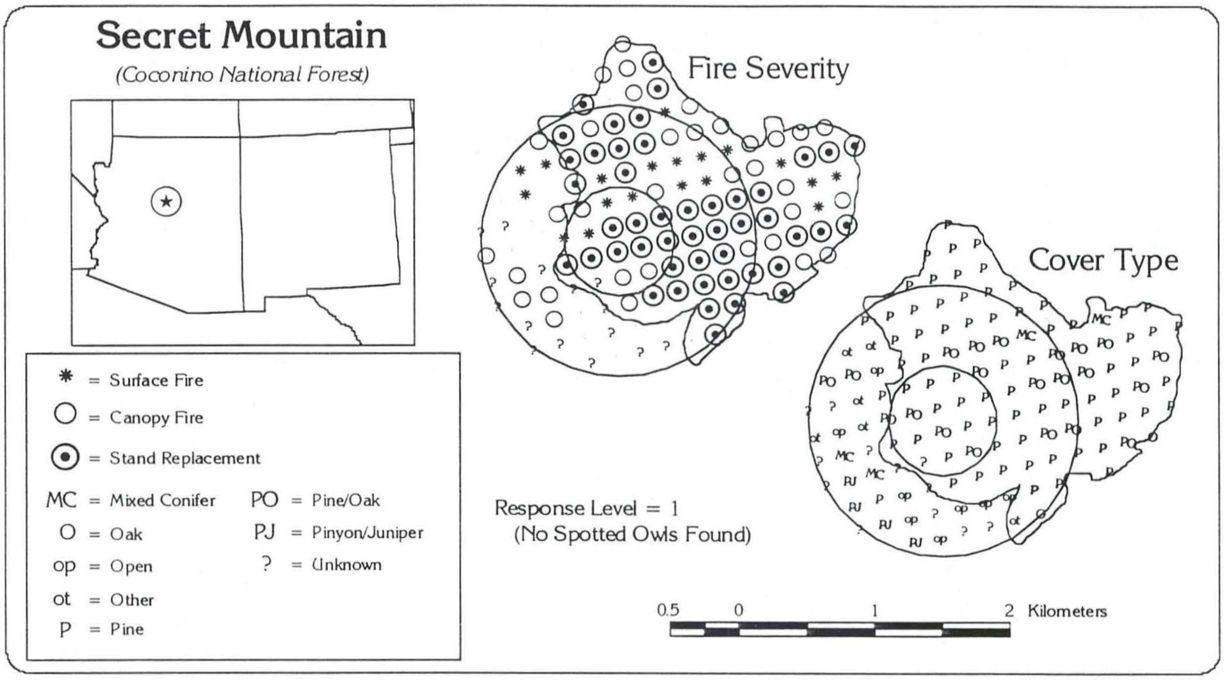


The Secret Canyon territory (MT #040605) is located on the Coconino National Forest southwest of Flagstaff, AZ. The original territory size is 205 hectares (508 acres) and the addition of our 1-km radius circle increased our survey area to 403 ha (995 ac). The original territory ranges in elevation from 1,536 - 1,960 meters (5,039 - 6,430 feet) and lies predominately on south- and north-facing slopes, with 45% of the territory having an aspect between 135°- 225° and 30% between 315°- 45°. The average slope over the territory is 30.6°. The Secret Canyon territory was paired with the unburned West Buzzard Point territory located approximately 6.5 kilometers to the north.

Along with the Secret Cabin and Secret Mountain territories, the Secret Canyon territory was burned by the Lost fire in 1994. We had 60 habitat survey points within this original territory boundary and 88% of these showed no evidence of recent fire. 7% showed only evidence of ground fire, 3% burned to some degree (but not completely) into the canopy and 0% showed complete stand replacement burn. 2% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 13% of the territory had a Pine cover type, 5% had a mixture of Pine and Oak, and 42% had a Mixed Conifer cover type. 38% was classified as "Other" and 2% was unknown.

Spotted Owl Monitoring History for Secret Canyon Territory (adapted from Randall-Parker [1996])							
1990	1991	1992	1993	1994	1995	1996	***1997***
Single	Single	Not Surveyed	Pair	Single	Not Surveyed	Not Surveyed	***Pair***

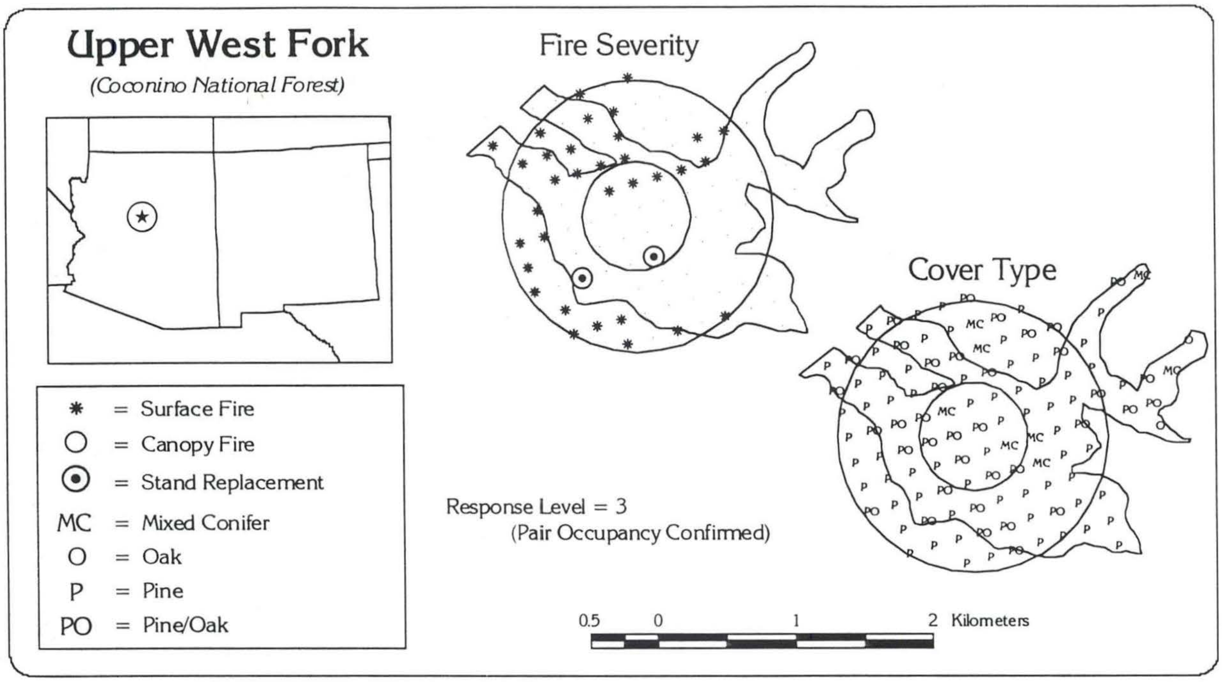


The Secret Mountain territory (MT #040604) is located on the Coconino National Forest southwest of Flagstaff, AZ. The original territory size is 319 hectares (788 acres) and the addition of our 1-km radius circle increased our survey area to 437 ha (1,081 ac). The original territory ranges in elevation from 1,709 - 2,015 meters (5,607 - 6,611 feet) and has a fairly equal distribution of north-, east-, south- and west-facing slopes. The average slope over the territory is 16.5°. The Secret Mountain territory was paired with the unburned Barney Springs territory located approximately 7.5 kilometers to the northeast.

Along with the Secret Cabin and Secret Canyon territories, the Secret Mountain territory was burned by the Lost fire in 1994. We had 91 habitat survey points within this original territory boundary and 3% of these showed no evidence of recent fire. 16% showed only evidence of ground fire, 29% burned to some degree (but not completely) into the canopy and 51% showed complete stand replacement burn. 1% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 73% of the territory had a Pine cover type, 20% had a mixture of Pine and Oak, and 2% had a Mixed Conifer cover type. 4% was classified as "Other" and 1% was unknown.

Spotted Owl Monitoring History for Secret Mountain Territory (adapted from Randall-Parker [1996])							
1990	1991	1992	1993	1994	1995	1996	***1997***
Pair	Pair	Absent	Pair	Single	Absent	Not Surveyed	***Absent***



The Upper West Fork territory (MT #040212) is located on the Coconino National Forest southwest of Flagstaff, AZ. The original territory size is 272 hectares (672 acres) and the addition of our 1-km radius circle increased our survey area to 386 ha (953 ac). The original territory ranges in elevation from 1,981 - 2,128 meters (6,499 - 6,981 feet) and has a fairly equal distribution of north-, east-, south- and west-facing slopes. The average slope over the territory is 15.0°. The Upper West Fork territory was paired with the unburned Rattlesnake territory located approximately 4.5 kilometers to the south.

Along with the Red Hill territory, the Upper West Fork territory was burned by the Hog/Red Hill Prescribed Fire in 1994 (Peaks 1996). We had 74 habitat survey points within this original territory boundary and 81% of these showed no evidence of recent fire. 16% showed only evidence of ground fire, 0% burned to some degree (but not completely) into the canopy and 3% showed complete stand replacement burn. 0% of the survey points were inaccessible or otherwise not surveyed.

Prior to the fire, 55% of the territory had a Pine cover type, 34% had a mixture of Pine and Oak, and 8% had a Mixed Conifer cover type. 3% was classified as "Other".

Spotted Owl Monitoring History for Upper West Fork Territory (adapted from Randall-Parker [1996])								
1989	1990	1991	1992	1993	1994	1995	1996	***1997***
Single	Nest (1 young)	Nest (2 young)	Pair	Nest (2 young)	Single	Single	Single	***Pair***

Case Summaries for OFS Territories, 1-km Circles and 400-m Circles

Table B1: Topographic Summaries for OFS Territories (Forest Service Delineated PACs and Cores)

Forest	Territory	Response Level[a]	Territory Size (Hectares)	Minimum Elevation (meters)	Maximum Elevation (meters)	Average Slope (Degrees)	% North Aspect	% East Aspect	% South Aspect	% West Aspect	Topographic Roughness Index[b]
Coconino	East Bear Jaw	1	301	2,357	2,660	16.07	37%	43%	2%	15%	148
	Hochderffer	1	270	2,459	2,782	15.52	29%	4%	18%	49%	143
	Orion Springs	3	260	2,451	2,907	13.22	0%	30%	58%	12%	122
	Red Hill	1	305	1,945	2,224	14.61	34%	16%	21%	29%	144
	Secret Cabin	3	199	1,826	2,005	13.25	29%	23%	25%	22%	123
	Secret Canyon	3	205	1,536	1,960	30.56	30%	17%	45%	8%	329
	Secret Mountain	1	319	1,709	2,015	16.52	27%	30%	21%	23%	167
	Upper West Fork	3	272	1,981	2,128	15.02	31%	25%	32%	12%	143
Coronado	Mormon Canyon	3	206	2,131	2,817	27.42	51%	0%	9%	40%	270
	Rattlesnake Peak	1	202	1,968	2,415	25.00	43%	20%	15%	22%	251
	Red Ridge	3	237	1,859	2,504	25.04	55%	31%	0%	14%	244
	Loma Linda	2	221	1,975	2,575	26.75	24%	28%	4%	45%	269
	Riggs Lake	4	285	2,484	2,829	14.37	14%	22%	28%	35%	132
	Miller Canyon	3	423	1,788	2,883	31.12	53%	25%	14%	8%	316
	Hunter Canyon	2	355	1,590	2,844	24.71	55%	37%	6%	1%	247
	Rucker Canyon	2	188	2,009	2,475	32.33	24%	32%	23%	21%	342
	Shovel Springs	2	174	2,114	2,691	26.67	39%	13%	6%	41%	268
	Romero Canyon	3	313	2,034	2,597	23.00	12%	12%	30%	45%	225
	Upper Cunningham	3	329	2,657	2,999	21.11	7%	12%	41%	40%	201
	Webb Peak	4	230	2,609	3,047	14.77	4%	37%	32%	28%	142
	Mill Site	1	267	2,621	3,147	19.59	42%	29%	5%	24%	184
Gila	Wilson	3	232	2,444	2,906	19.53	28%	35%	0%	37%	185
	Piney Park	1	313	2,497	2,881	18.88	29%	1%	45%	25%	179
	Juniper Saddle	3	238	2,268	2,575	16.93	46%	18%	4%	32%	163
	Gila Woods	1	313	2,280	2,651	17.75	48%	12%	2%	39%	169
	Tadpole #1	2	196	2,220	2,601	22.72	70%	27%	0%	3%	222
	Tadpole #2	3	181	2,185	2,558	14.75	77%	12%	0%	11%	143
	Tadpole #3	2	230	2,279	2,622	20.72	69%	27%	1%	4%	203

Table B1: Topographic Summaries for OFS Territories (Forest Service Delineated PACs and Cores)											
Forest	Territory	Response Level[a]	Territory Size (Hectares)	Minimum Elevation (meters)	Maximum Elevation (meters)	Average Slope (Degrees)	% North Aspect	% East Aspect	% South Aspect	% West Aspect	Topographic Roughness Index[b]
Lincoln	**Bridge**	4	291	2,331	2,531	13.26	21%	25%	42%	13%	130
	Fire	1	274	2,051	2,251	13.91	33%	21%	40%	7%	119
	Carr	1	255	2,051	2,280	16.40	29%	21%	46%	4%	157
	Circle Cross	2	195	2,341	2,719	16.17	6%	7%	49%	38%	156
	Scott Able	3	189	2,359	2,658	18.66	19%	19%	20%	42%	179

[a]*Response Level: 1 = No Owls, 2 = Single Owl, 3 = Pair of Owls, 4 = Reproducing Pair*
[b]*Topographic Roughness = Length of 20m Contour Lines per hectare*

Table B2: Fire and Vegetative Summaries for OFS Territories (Forest Service Delineated PACs and Cores)

Forest	Territory	Response Level[a]	# Survey Points	Fire Severity				Cover Type				% Unsurveyed
				% Unburned	% Ground Fire	% Canopy Fire	% Stand Replacement Fire	% Pine	% Pine/ Oak	% Mixed Conifer	% Other Species	
Coconino	East Bear Jaw	1	84	26%	37%	1%	36%	40%	0%	56%	4%	0%
	Hochderffer	1	80	71%	11%	5%	13%	56%	0%	24%	20%	0%
	Orion Springs	3	75	93%	7%	0%	0%	25%	0%	49%	25%	0%
	Red Hill	1	88	72%	28%	0%	0%	50%	40%	6%	5%	0%
	Secret Cabin	3	58	55%	41%	0%	3%	48%	33%	7%	12%	0%
	Secret Canyon	3	60	88%	7%	3%	0%	13%	5%	42%	38%	2%
	Secret Mountain	1	91	3%	16%	29%	51%	73%	20%	2%	4%	1%
	Upper West Fork	3	74	81%	16%	0%	3%	55%	34%	8%	3%	0%
Coronado	Mormon Canyon	3	61	49%	21%	16%	13%	30%	3%	59%	8%	0%
	Rattlesnake Peak	1	59	22%	53%	19%	7%	39%	46%	7%	8%	0%
	Red Ridge	3	71	83%	17%	0%	0%	20%	24%	48%	8%	0%
	Loma Linda	2	69	90%	10%	0%	0%	39%	26%	13%	22%	0%
	Riggs Lake	4	83	46%	28%	19%	6%	41%	4%	47%	7%	1%
	Miller Canyon	3	124	51%	31%	5%	8%	2%	9%	56%	27%	6%
	Hunter Canyon	2	106	27%	21%	2%	39%	8%	17%	7%	58%	11%
	Rucker Canyon	2	56	75%	4%	4%	0%	5%	11%	30%	36%	18%
	Shovel Springs	2	54	7%	28%	30%	35%	20%	11%	69%	0%	0%
	Romero Canyon	3	98	49%	22%	15%	13%	26%	54%	13%	7%	0%
	Upper Cunningham	3	97	87%	6%	4%	3%	19%	0%	75%	6%	0%
	Webb Peak	4	66	50%	20%	8%	23%	17%	0%	74%	9%	0%
	Mill Site	1	74	73%	18%	7%	3%	0%	0%	92%	8%	0%
Gila	Wilson	3	69	1%	42%	33%	23%	14%	0%	84%	1%	0%
	Piney Park	1	88	3%	15%	35%	47%	80%	7%	13%	1%	0%
	Juniper Saddle	3	69	1%	49%	41%	9%	84%	7%	7%	1%	0%
	Gila Woods	1	89	2%	43%	39%	16%	82%	1%	16%	1%	0%
	Tadpole #1	2	57	5%	46%	32%	18%	25%	11%	65%	0%	0%
	Tadpole #2	3	50	6%	62%	26%	6%	18%	26%	50%	6%	0%
	Tadpole #3	2	66	18%	50%	18%	14%	11%	17%	68%	5%	0%

Table B2: Fire and Vegetative Summaries for OFS Territories (Forest Service Delineated PACs and Cores)

Forest	Territory	Response Level[a]	# Survey Points	Fire Severity: % Unburned	Fire Severity: % Ground Fire	Fire Severity: % Canopy Fire	Fire Severity: % Stand Replacement Fire	Cover Type: % Pine	Cover Type: % Pine/ Oak	Cover Type: % Mixed Conifer	Cover Type: % Other Species	% Unsurveyed
Lincoln	Bridge	4	83	22%	12%	35%	27%	24%	4%	67%	0%	5%
	Fire	1	78	49%	41%	8%	3%	49%	1%	3%	47%	0%
	Carr	1	73	29%	26%	4%	41%	38%	16%	10%	36%	0%
	Circle Cross	2	56	0%	7%	38%	55%	0%	0%	100%	0%	0%
	Scott Able	3	54	96%	4%	0%	0%	2%	2%	96%	0%	0%

[a]*Response Level: 1 = No Owls, 2 = Single Owl, 3 = Pair of Owls, 4 = Reproducing Pair*

Table B3: Topographic Summaries for 1-km Circular Activity Centers (CACs)

Forest	Territory	Response Level[a]	Territory Size (Hectares)	Minimum Elevation (meters)	Maximum Elevation (meters)	Average Slope (Degrees)	% North Aspect	% East Aspect	% South Aspect	% West Aspect	Topographic Roughness Index[b]
Coconino	East Bear Jaw	1	313	2,295	2,579	12.55	41%	40%	2%	18%	118
	Hochderffer	1	313	2,514	2,785	12.29	17%	6%	25%	52%	112
	Orion Springs	3	313	2,442	2,698	10.32	0%	24%	55%	21%	95
	Red Hill	1	313	1,882	2,171	12.36	33%	8%	18%	41%	128
	Secret Cabin	3	313	1,667	2,021	17.54	21%	15%	37%	27%	179
	Secret Canyon	3	313	1,546	2,036	25.34	22%	9%	55%	15%	263
	Secret Mountain	1	313	1,602	2,015	22.22	26%	26%	25%	23%	239
	Upper West Fork	3	313	1,988	2,142	12.64	28%	25%	33%	13%	121
Coronado	Mormon Canyon	3	313	2,180	2,817	28.57	43%	0%	17%	39%	285
	Rattlesnake Peak	1	313	2,020	2,445	26.00	35%	17%	23%	25%	264
	Red Ridge	3	313	1,996	2,580	24.82	50%	30%	6%	14%	243
	Loma Linda	2	313	1,902	2,468	26.28	26%	28%	1%	44%	260
	Riggs Lake	4	313	2,493	2,852	16.16	17%	18%	31%	34%	151
	Miller Canyon	3	313	1,867	2,839	32.75	52%	28%	16%	5%	335
	Hunter Canyon	2	313	1,715	2,446	27.76	45%	48%	7%	0%	276
	Rucker Canyon	2	313	1,963	2,477	31.87	15%	25%	32%	28%	333
	Shovel Springs	2	313	2,025	2,679	26.83	32%	12%	9%	47%	267
	Romero Canyon	3	313	2,034	2,597	23.00	12%	12%	30%	45%	225
	Upper Cunningham	3	313	2,643	3,084	20.97	10%	13%	33%	44%	201
	Webb Peak	4	313	2,231	2,947	25.89	2%	23%	39%	36%	264
	Mill Site	1	313	2,508	2,923	21.25	38%	33%	11%	19%	205
Gila	Wilson	3	313	2,278	2,650	16.57	38%	17%	7%	38%	156
	Piney Park	1	313	2,497	2,881	18.88	29%	1%	45%	25%	179
	Juniper Saddle	3	313	2,420	2,748	14.28	41%	3%	17%	39%	135
	Gila Woods	1	313	2,280	2,651	17.75	48%	12%	2%	39%	169
	Tadpole #1	2	313	2,109	2,604	16.55	62%	22%	5%	12%	161
	Tadpole #2	3	313	2,219	2,583	19.11	52%	10%	26%	12%	184
	Tadpole #3	2	313	2,210	2,609	13.53	70%	16%	5%	9%	131

Table B3: Topographic Summaries for 1-km Circular Activity Centers (CACs)

Forest	Territory	Response Level[a]	Territory Size (Hectares)	Minimum Elevation (meters)	Maximum Elevation (meters)	Average Slope (Degrees)	% North Aspect	% East Aspect	% South Aspect	% West Aspect	Topographic Roughness Index[b]
Lincoln	**Bridge**	4	313	2335.00	2517.00	13.91	25%	31%	34%	10%	135
	Fire	1	313	2093.00	2257.00	12.64	31%	26%	35%	9%	119
	Carr	1	313	2127.00	2340.00	16.43	44%	16%	36%	4%	158
	Circle Cross	2	313	2366.00	2746.00	16.42	4%	10%	49%	37%	159
	Scott Able	3	313	2373.00	2690.00	18.62	8%	23%	33%	36%	178

[a]*Response Level: 1 = No Owls, 2 = Single Owl, 3 = Pair of Owls, 4 = Reproducing Pair*

[b]*Topographic Roughness = Length of 20m Contour Lines per hectare*

Table B4: Fire and Vegetative Summaries for 1-km CACs													
				Fire Severity				Cover Type					
Forest	Territory	Response Level[a]	# Survey Points	% Unburned	% Ground Fire	% Canopy Fire	% Stand Replacement Fire	% Pine	% Pine/ Oak	% Mixed Conifer	% Other Species	% Unsurveyed
Coconino	East Bear Jaw	1	90	53%	27%	1%	19%	70%	0%	28%	2%	0%
	Hochderffer	1	89	96%	2%	0%	2%	71%	0%	13%	16%	0%
	Orion Springs	3	87	99%	1%	0%	0%	59%	0%	23%	18%	0%
	Red Hill	1	89	67%	33%	0%	0%	58%	31%	2%	8%	0%
	Secret Cabin	3	87	64%	26%	0%	0%	33%	32%	3%	22%	9%
	Secret Canyon	3	92	85%	10%	3%	0%	24%	15%	34%	25%	2%
	Secret Mountain	1	87	14%	15%	20%	38%	47%	17%	3%	18%	14%
	Upper West Fork	3	89	64%	34%	0%	2%	61%	33%	7%	0%	0%
Coronado	Mormon Canyon	3	92	55%	21%	12%	7%	35%	20%	26%	14%	5%
	Rattlesnake Peak	1	90	22%	52%	13%	12%	40%	36%	10%	14%	0%
	Red Ridge	3	96	65%	18%	2%	0%	18%	25%	32%	9%	16%
	Loma Linda	2	97	65%	14%	2%	0%	29%	25%	10%	18%	19%
	Riggs Lake	4	88	31%	34%	26%	8%	35%	7%	47%	10%	1%
	Miller Canyon	3	95	43%	25%	5%	11%	3%	11%	45%	25%	16%
	Hunter Canyon	2	95	13%	28%	3%	52%	5%	24%	8%	58%	4%
	Rucker Canyon	2	91	65%	4%	6%	1%	7%	12%	24%	33%	24%
	Shovel Springs	2	91	18%	35%	21%	23%	18%	12%	66%	1%	3%
	Romero Canyon	3	98	49%	22%	15%	13%	26%	54%	13%	7%	0%
	Upper Cunningham	3	90	88%	12%	0%	0%	13%	0%	80%	7%	0%
	Webb Peak	4	92	9%	32%	22%	32%	8%	2%	77%	7%	7%
	Mill Site	1	91	79%	20%	1%	0%	14%	0%	77%	9%	0%
Gila	Wilson	3	90	2%	41%	44%	12%	73%	1%	22%	3%	0%
	Piney Park	1	88	3%	15%	35%	47%	80%	7%	13%	1%	0%
	Juniper Saddle	3	89	1%	11%	33%	55%	91%	0%	9%	0%	0%
	Gila Woods	1	89	2%	43%	39%	16%	82%	1%	16%	1%	0%
	Tadpole #1	2	92	20%	43%	27%	10%	30%	23%	42%	4%	0%
	Tadpole #2	3	87	40%	28%	25%	7%	25%	13%	44%	18%	0%
	Tadpole #3	2	88	7%	73%	14%	6%	17%	49%	28%	5%	1%

Table B4: Fire and Vegetative Summaries for 1-km CACs

Forest	Territory	Response Level[a]	# Survey Points	Fire Severity: % Unburned	Fire Severity: % Ground Fire	Fire Severity: % Canopy Fire	Fire Severity: % Stand Replacement Fire	Cover Type: % Pine	Cover Type: % Pine/ Oak	Cover Type: % Mixed Conifer	Cover Type: % Other Species	% Unsurveyed
Lincoln	Bridge	4	88	25%	14%	26%	31%	20%	2%	70%	2%	5%
	Fire	1	93	33%	58%	8%	0%	45%	1%	2%	51%	1%
	Carr	1	91	7%	12%	10%	71%	73%	11%	3%	13%	0%
	Circle Cross	2	89	3%	6%	37%	54%	0%	0%	100%	0%	0%
	Scott Able	3	89	92%	7%	1%	0%	2%	1%	96%	1%	0%

[a]*Response Level: 1 = No Owls, 2 = Single Owl, 3 = Pair of Owls, 4 = Reproducing Pair*

Table B5: Topographic Summaries for 400-m CACs

Forest	Territory	Response Level[a]	Territory Size (Hectares)	Minimum Elevation (meters)	Maximum Elevation (meters)	Average Slope (Degrees)	% North Aspect	% East Aspect	% South Aspect	% West Aspect	Topographic Roughness Index[b]
Coconino	East Bear Jaw	1	50	2,338	2,497	13.6	18%	66%	7%	9%	118
	Hochderffer	1	50	2,568	2,708	10.3	10%	0%	16%	74%	98
	Orion Springs	3	50	2,500	2,629	10.4	0%	32%	54%	14%	96
	Red Hill	1	50	2,034	2,107	6.9	32%	5%	10%	53%	72
	Secret Cabin	3	50	1,804	1,996	14.0	22%	13%	40%	25%	134
	Secret Canyon	3	50	1,628	2,025	30.2	23%	6%	54%	17%	323
	Secret Mountain	1	50	1,884	2,014	11.6	25%	19%	20%	36%	106
	Upper West Fork	3	50	2,004	2,122	15.7	49%	13%	27%	10%	160
Coronado	Mormon Canyon	3	50	2,310	2,614	29.0	50%	1%	18%	31%	290
	Rattlesnake Peak	1	50	2,082	2,332	25.5	40%	36%	2%	21%	260
	Red Ridge	3	50	2,121	2,432	25.0	62%	12%	0%	25%	243
	Loma Linda	2	50	1,972	2,284	30.5	24%	39%	0%	37%	308
	Riggs Lake	4	50	2,670	2,816	13.8	38%	10%	18%	35%	127
	Miller Canyon	3	50	2,011	2,465	32.8	91%	4%	1%	4%	326
	Hunter Canyon	2	50	1,826	2,152	29.8	49%	43%	9%	0%	298
	Rucker Canyon	2	50	2,024	2,359	34.0	16%	47%	22%	14%	375
	Shovel Springs	2	50	2,161	2,475	26.9	22%	2%	16%	61%	276
	Romero Canyon	3	50	2,141	2,421	23.9	20%	9%	16%	55%	235
	Upper Cunningham	3	50	2,695	2,972	21.4	13%	4%	10%	74%	208
	Webb Peak	4	50	2,506	2,871	25.6	1%	14%	46%	39%	265
	Mill Site	1	50	2,670	2,863	19.4	20%	49%	31%	0%	184
Gila	Wilson	3	50	2,347	2,527	18.9	41%	8%	0%	52%	181
	Piney Park	1	50	2,586	2,783	18.2	18%	1%	54%	27%	172
	Juniper Saddle	3	50	2,497	2,622	13.7	37%	0%	33%	30%	132
	Gila Woods	1	50	2,345	2,533	21.2	42%	9%	0%	49%	203
	Tadpole #1	2	50	2,183	2,437	17.8	78%	20%	0%	2%	168
	Tadpole #2	3	50	2,303	2,576	20.9	68%	17%	11%	3%	201
	Tadpole #3	2	50	2,271	2,400	11.0	67%	21%	0%	12%	108

Table B5: Topographic Summaries for 400-m CACs

Forest	Territory	Response Level[a]	Territory Size (Hectares)	Minimum Elevation (meters)	Maximum Elevation (meters)	Average Slope (Degrees)	% North Aspect	% East Aspect	% South Aspect	% West Aspect	Topographic Roughness Index[b]
Lincoln	Bridge	4	50	2,369	2,491	15.4	19%	21%	34%	27%	152
	Fire	1	50	2,120	2,227	12.7	35%	34%	31%	0%	114
	Carr	1	50	2,168	2,279	16.3	40%	25%	26%	9%	154
	Circle Cross	2	50	2,437	2,614	15.6	0%	0%	47%	52%	150
	Scott Able	3	50	2,401	2,559	17.5	3%	37%	34%	26%	165

[a]*Response Level: 1 = No Owls, 2 = Single Owl, 3 = Pair of Owls, 4 = Reproducing Pair*

[b]*Topographic Roughness = Length of 20m Contour Lines per hectare*

Table B6: Fire and Vegetative Summaries for 400-m CACs

Forest	Territory	Response Level	# Survey Points	Fire Severity: % Unburned	Fire Severity: % Ground Fire	Fire Severity: % Canopy Fire	Fire Severity: % Stand Replacement Fire	Cover Type: % Pine	Cover Type: % Pine/ Oak	Cover Type: % Mixed Conifer	Cover Type: % Other Species	% Unsurveyed
Coconino	East Bear Jaw	0	14	93%	7%	0%	0%	36%	0%	64%	0%	0%
	Hochderffer	1	16	100%	0%	0%	0%	69%	0%	13%	19%	0%
	Orion Springs	3	14	100%	0%	0%	0%	36%	0%	36%	29%	0%
	Red Hill	1	16	69%	31%	0%	0%	88%	6%	0%	6%	0%
	Secret Cabin	3	14	64%	36%	0%	0%	36%	36%	14%	14%	0%
	Secret Canyon	3	15	100%	0%	0%	0%	27%	0%	33%	40%	0%
	Secret Mountain	1	14	0%	21%	21%	50%	71%	21%	0%	0%	7%
	Upper West Fork	3	14	71%	21%	0%	7%	43%	43%	14%	0%	0%
Coronado	Mormon Canyon	3	16	81%	19%	0%	0%	50%	13%	31%	6%	0%
	Rattlesnake Peak	1	16	13%	81%	6%	0%	38%	50%	6%	6%	0%
	Red Ridge	3	15	73%	27%	0%	0%	33%	13%	53%	0%	0%
	Loma Linda	2	16	56%	31%	6%	0%	25%	38%	6%	25%	6%
	Riggs Lake	4	14	21%	64%	14%	0%	7%	0%	86%	7%	0%
	Miller Canyon	3	15	33%	33%	20%	13%	0%	20%	67%	13%	0%
	Hunter Canyon	2	15	7%	27%	7%	60%	7%	20%	7%	67%	0%
	Rucker Canyon	2	15	67%	0%	0%	0%	0%	13%	13%	40%	33%
	Shovel Springs	2	14	14%	36%	21%	29%	0%	14%	86%	0%	0%
	Romero Canyon	3	16	31%	38%	31%	0%	19%	50%	19%	13%	0%
	Upper Cunningham	3	16	88%	13%	0%	0%	0%	0%	88%	13%	0%
	Webb Peak	4	15	7%	40%	20%	33%	13%	0%	87%	0%	0%
	Mill Site	1	15	80%	13%	7%	0%	13%	0%	80%	7%	0%
Gila	Wilson	3	14	0%	64%	36%	0%	64%	0%	36%	0%	0%
	Piney Park	1	14	0%	7%	14%	79%	86%	0%	14%	0%	0%
	Juniper Saddle	3	14	0%	14%	29%	57%	93%	0%	7%	0%	0%
	Gila Woods	1	15	7%	53%	27%	13%	87%	0%	13%	0%	0%
	Tadpole #1	2	14	0%	64%	21%	14%	29%	14%	57%	0%	0%
	Tadpole #2	3	16	56%	19%	19%	6%	6%	6%	63%	25%	0%
	Tadpole #3	2	15	0%	80%	13%	7%	27%	53%	13%	7%	0%

Table B6: Fire and Vegetative Summaries for 400-m CACs

Forest	Territory	Response Level	# Survey Points	Fire Severity: % Unburned	Fire Severity: % Ground Fire	Fire Severity: % Canopy Fire	Fire Severity: % Stand Replacement Fire	Cover Type: % Pine	Cover Type: % Pine/ Oak	Cover Type: % Mixed Conifer	Cover Type: % Other Species	% Unsurveyed
Lincoln	Bridge	4	14	21%	7%	43%	29%	29%	0%	71%	0%	0%
	Fire	1	13	69%	31%	0%	0%	38%	8%	8%	46%	0%
	Carr	1	13	0%	8%	8%	85%	31%	38%	15%	15%	0%
	Circle Cross	2	14	0%	7%	29%	64%	0%	0%	100%	0%	0%
	Scott Able	3	16	100%	0%	0%	0%	0%	0%	100%	0%	0%

[a]Response Level: 1 = No Owls, 2 = Single Owl, 3 = Pair of Owls, 4 = Reproducing Pair

APPENDIX C: CART Analyses on Point Data

400-m CACs 130
OFS Territories 130
1-km CACs 130

400-m CACs

Predictive Accuracy	Classification	Criteria
28%	Unburned	Vegetation = Other
36%	Ground	Pine/Oak; Slope > 7 Mixed Conifer or Pine; Slope 7 - 15; North
32%	Canopy	Mixed Conifer or Pine; Slope 7 - 16; East, South or West Mixed Conifer or Pine; East, South or West; Slope > 21 Mixed Conifer or Pine; North; Slope > 15
25%	Stand Replacement	Mixed Conifer, Pine or Pine/Oak; Slope < 7 Mixed Conifer or Pine; East, South or West; Slope 16 - 21

OFS Territories

Predictive Accuracy	Classification	Criteria
33%	Unburned	Pine/Oak or Other; South or West Other; North or East Mixed Conifer; Slope 3 - 7; North or East Mixed Conifer; Slope 23 - 39
21%	Ground	Pine/Oak; North or East; Slope 6 - 36 Pine; Slope 16 - 19; North or West Mixed Conifer; Slope 7 - 19; North or East Mixed Conifer; Slope 23 - 36; East, South or West Mixed Conifer; Slope 36 - 39
43%	Canopy	Pine; Slope 6 - 16; North or West Pine; Slope 6 - 17; South or East Pine; Slope 19 - 28; West Pine; Slope = 19; North, East or South Pine; Slope 22 - 28; North, East or South Mixed Conifer; Slope 3 - 20; South or West Mixed Conifer; Slope 23 - 36; North
29%	Stand Replacement	Pine/Oak; North or East; Slope < 6 Pine/Oak; North or East; Slope > 36 Pine; Slope < 6 Pine; Slope 17 - 19; South or East Pine; Slope 19 22; North, East or South Pine; Slope > 28 Mixed Conifer; Slope < 3 Mixed Conifer; Slope 20 - 23; South or West Mixed Conifer; Slope 19 - 23; North or East Mixed Conifer; Slope 19 - 23; North or East

1-km CACs

Predictive Accuracy	Classification	Criteria
45%	Unburned	Pine/Oak or Other; South or West Mixed Conifer or Pine; Slope < 6 Mixed Conifer or Pine; Slope 6 - 8; South or East Mixed Conifer or Pine; Slope > 28; East, South or West
16%	Ground	Pine/Oak or Other; North or East
43%	Canopy	Mixed Conifer or Pine; Slope 6 - 28; North or West
29%	Stand Replacement	Mixed Conifer or Pine; Slope 8 - 28; South or East

Overall predictive accuracy is 0.32579778